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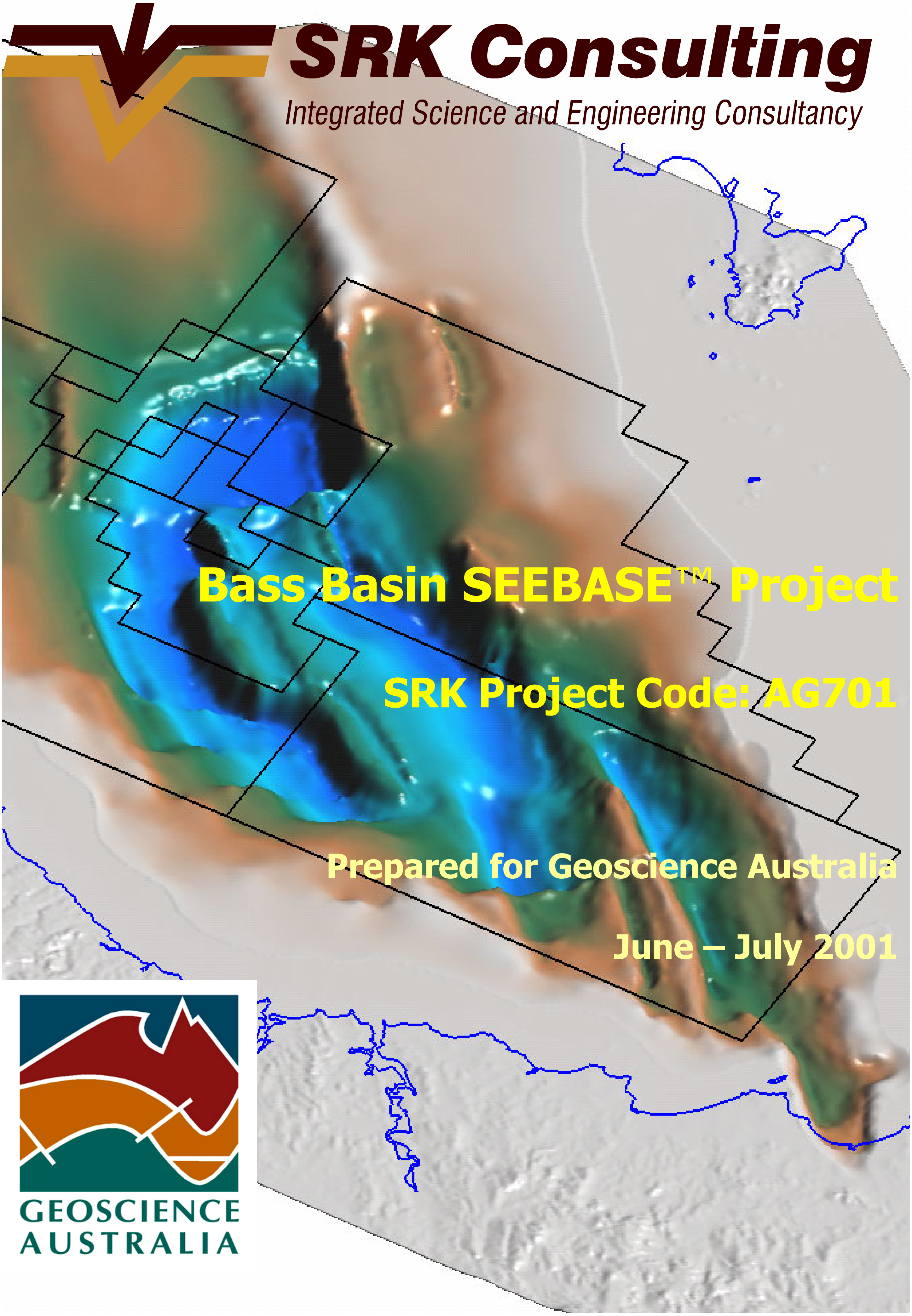

Bass Basin SEEBASE™ Project

SRK Project Code: AG701

Prepared for Geoscience Australia

June – July 2001

GEOSCIENCE AUSTRALIA

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***SEEBASE™** = **S**tructurally **E**nhanced view of **E**conomic **Base**ment

GEOSCIENCE AUSTRALIA

SRK Consulting
Integrated Science and Engineering Consultancy
Steffen, Robertson & Kirsten (Australasia) Pty. Ltd., ABN 56 074 271 720, trading as SRK Consulting

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Executive Summary

This project was initiated by Geoscience Australia (formerly AGSO) to provide an integrated regional interpretation of basement composition, structure and depth in the Bass Basin, and investigate the effect of basement geology on basin evolution and petroleum systems. SRK Consulting was contracted by Geoscience Australia in June 2001.

SRKís approach primarily relies on the interpretation of magnetic and gravity data, calibrated with many other datasets including mapped geology, event histories, wells and seismic. SRK utilizes a ìbottom-upî approach to basin analysis, starting with a rigorous understanding of basement geology. By integrating the plate-scale kinematic event history for the area of interest, an interpretation of the basinís structural evolution through time can be mapped. Combined with a SEEBASE™* map of depth to basement, this data can be used to understand basin phase architecture and the petroleum systemsdeveloped within the basin.

The key findings of this project are as follows:

- The basement geology of the Bass Basin is dominated by two key Neoproterozoic to Paleozoic basement terranes; the Kanmantoo and Lachlan Fold Belts.
- The boundary between the 2 basement terranes is the Moyston-Tamar Fault Zone; a major NW trending array of structures which later became the locus of Mesozoic extension.
- The present-day geometry of the Bass Basin was established during early Cretaceous NE-SW extension.
- Basin architecture is largely controlled by basement structures, composition, fabric and rheology.
- NW trending basement shear zones/terrane boundaries were a first-order control on basin evolution during the Mesozoic.
- NE trending early Carboniferous faults were a second-order control on basin evolution during the Mesozoic.
- The geometry of the Bass Basin is defined by deep half-graben compartmentalized by major accommodation zones and/or transfer faults.
- Seven basin phases/tectonic events have shaped the Bass during the Mesozoic and Tertiary.
- A SEEBASE™* model for the Bass Basin shows basement topography, and can be used to map play element distribution, migration pathways and trap type/distribution.

*SEEBASE™ = Structurally Enhanced view of Economic Basement

Recommendations

- Extend this study to encompass all basins in the Bass Strait area, including the Otway, Sorrell and Gippsland Basins.
- This projects provides new base to investigate the stratigraphic evolution of the Bass Basin. A sequence stratigraphic study based on the structural framework and SEEBASE™ model presented here would provide new insights into the evolution of the Bass Basin petroleum systems.
- More detailed SEEBASE™ study of prospective areas/permits integrating all available seismic data. Parts of the existing magnetic dataset can support much more detailed work than done in this project, and a full seismic calibration would provide additional constraints on structural geometries at depth and reactivation histories.
- Acquire new aeromagnetic data in areas of very poor data quality (ie approximately the northern half of the Bass Basin). This would enable the interpretation presented here to be significantly improved. Such data would also enable interpretation of intrasedimentary features such as basin floor fans/deltas, basement-detached faults and volcanics.
- Paleogeographic analysis and basin modeling to track accommodation space through time using SEEBASE™ as a starting point. This would resolve the relative effects of the early and late Cretaceous extension, and the extent and nature of any late Jurassic depocentres.

Project Background

- This project was initiated by AGSO as part of the Southeast Basins Program to attract new explorers to the Bass Basin by providing new insights into its geology and hence reduce exploration risk.
- SRK Consulting was contracted by AGSO in June 2001.
- This project was completed in 4 weeks by the SRK Energy Services team.

Project Aims

- To provide an integrated regional interpretation of basement composition, structure and depth in the Bass Basin, utilizing available gravity, magnetic, seismic and other data.
- To investigate the effects of basement geology on basin evolution and petroleum systems in the Bass Basin, focusing on structural evolution/reactivation, basin architecture and tectonic history.
- To provide an ArcView GIS containing all interpretive layers.

Why SRK?

- SRK Consulting is one of the world's largest natural resource consultancies, with 22 offices in 5 continents.
- The SRK Energy Services group is based in Canberra, Australia. We are leaders in innovative, integrated *geological* interpretation of non-seismic and seismic data, principally magnetic and gravity data. We have worldwide experience in the petroleum, minerals and coal sectors.
- SRK Energy Services has worldwide experience in basin analysis, and has pioneered many new techniques for rapidly evaluating the structural framework and tectonic evolution of all types of basins, based largely on geopotential field data. SRK utilizes a "bottom-up" approach to basin analysis, starting with a rigorous understanding of basement geology. By integrating the plate-scale kinematic event history for the area of interest, a interpretation of the basinís structural evolution through time can be mapped. Combined with a SEEBASE™* map of depth to basement, this data can be used to understand basin phase distribution and petroleum systems. (*SEEBASE™ = Structurally Enhanced view of Economic Basement)

Datasets

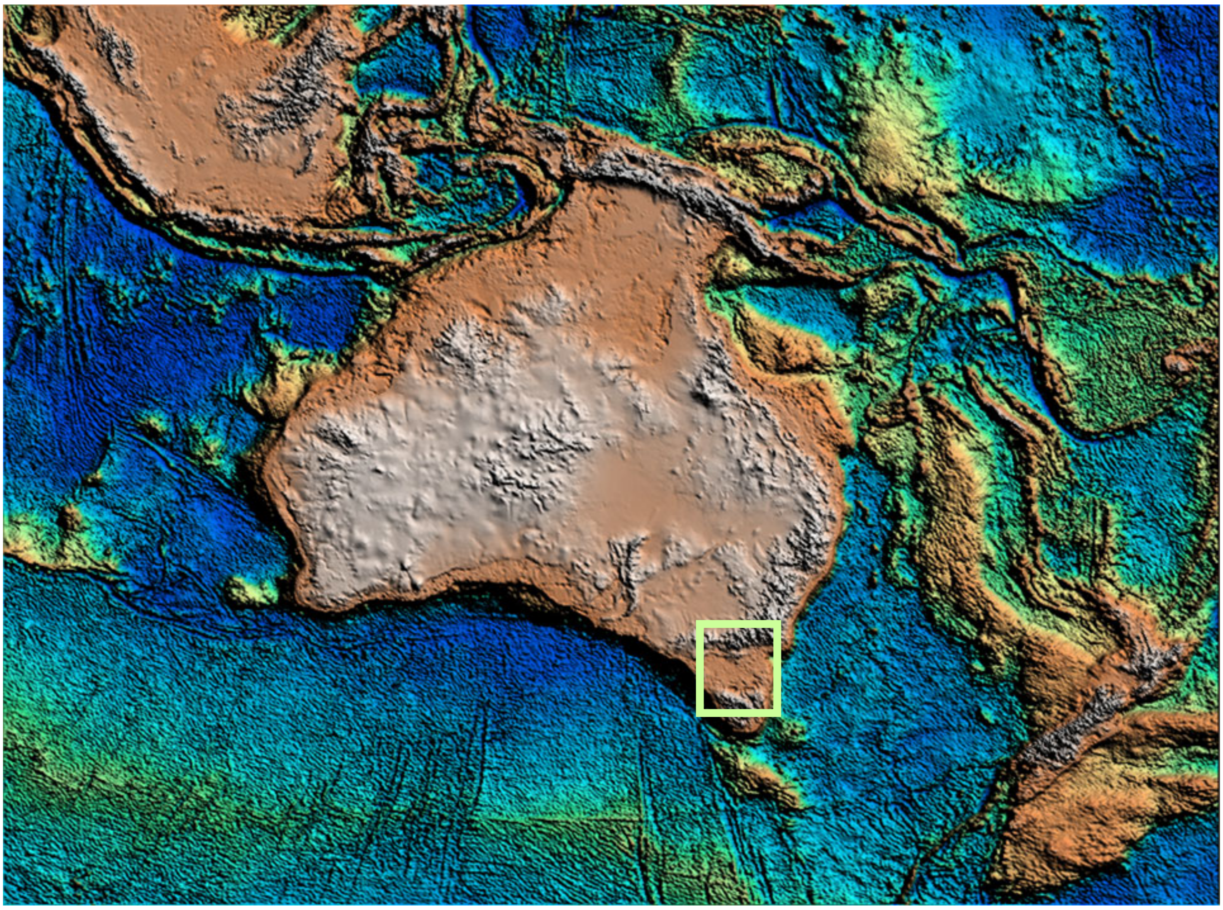
The following datasets were provided by AGSO for the Bass SEEBASE™ project:

- Gravity (new 2001 AGSO 800m grid)
- Magnetics (various datasets)
- DEM (Auslig 9 sec)
- Seismic (data held in-house by AGSO)
- Wells (completion reports, summary logs)

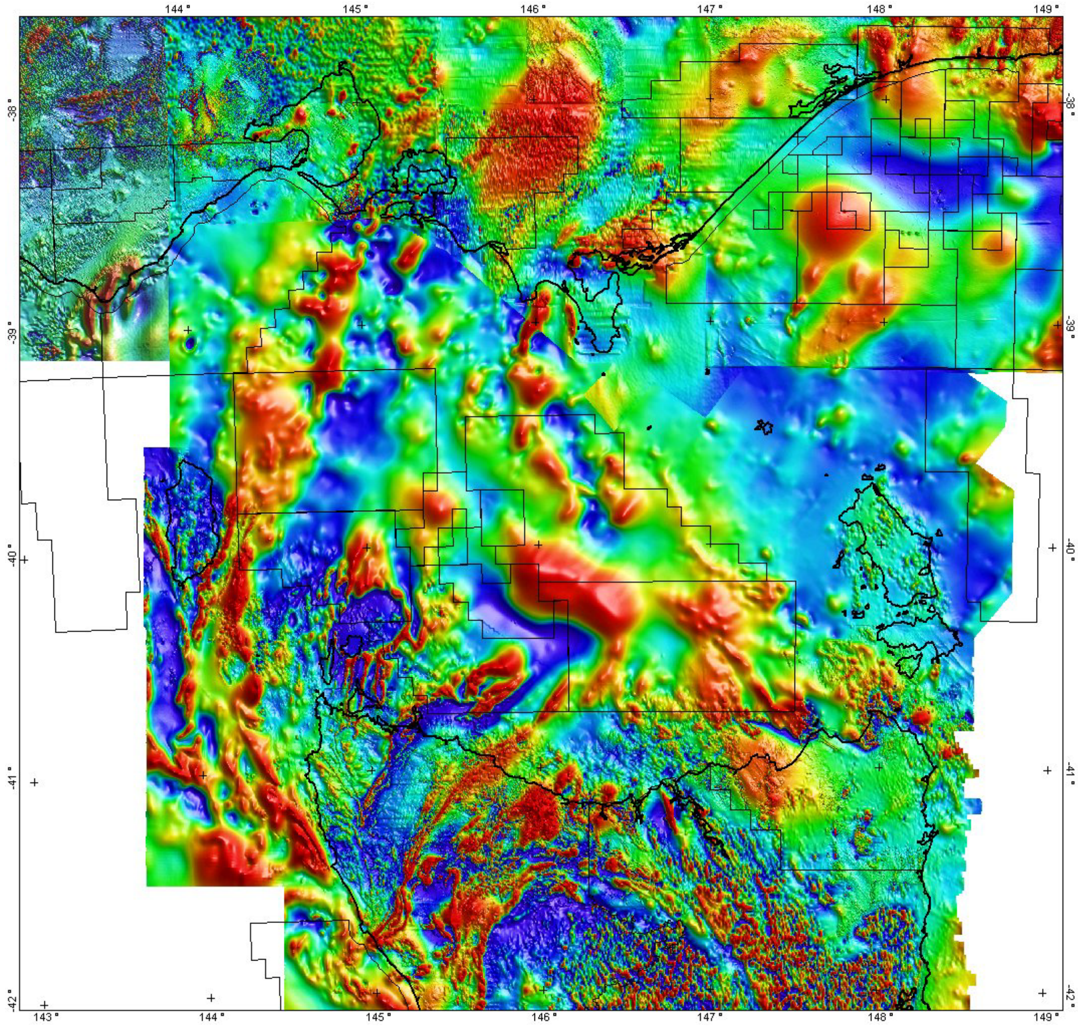
Various magnetic datasets were also obtained (at no cost) from the Geological Survey of Victoria.

In addition, SRK integrated its extensive in-house knowledge of Australian geology, published literature, and plate tectonic reconstructions

Project Area



Magnetics



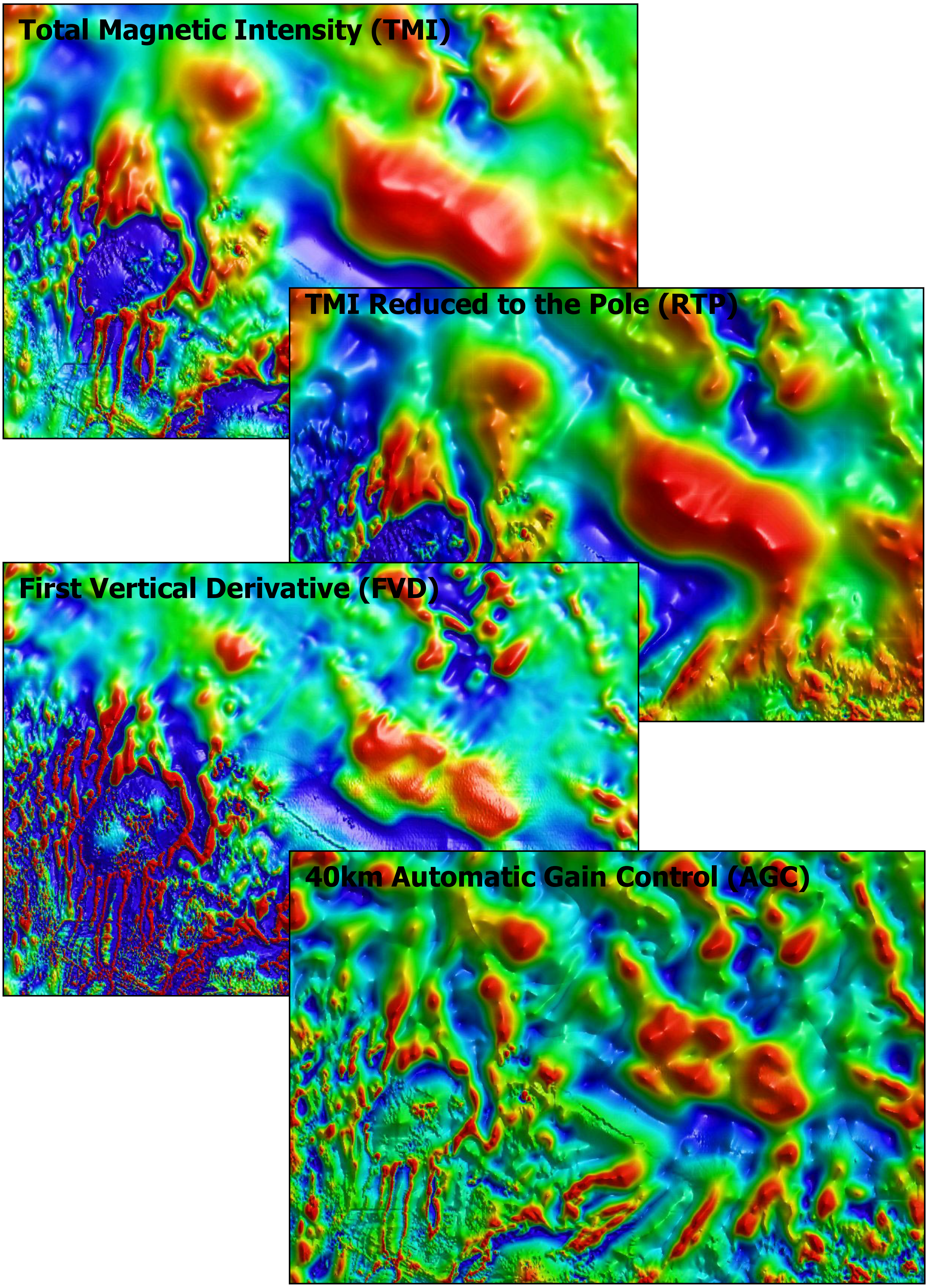
HSI image of Total Magnetic Intensity

Aeromagnetic data measures variations in the Earth's magnetic field caused by variations in the magnetic susceptibility of the underlying rocks. It provides information on the structure and composition of the magnetic basement. Most bodies within the basement have a distinctive magnetic signature which is characterized by the magnitude, heterogeneity and fabric of the magnetic signal. When calibrated with known geology, terranes can be mapped under a cover of sedimentary rock and/or water.

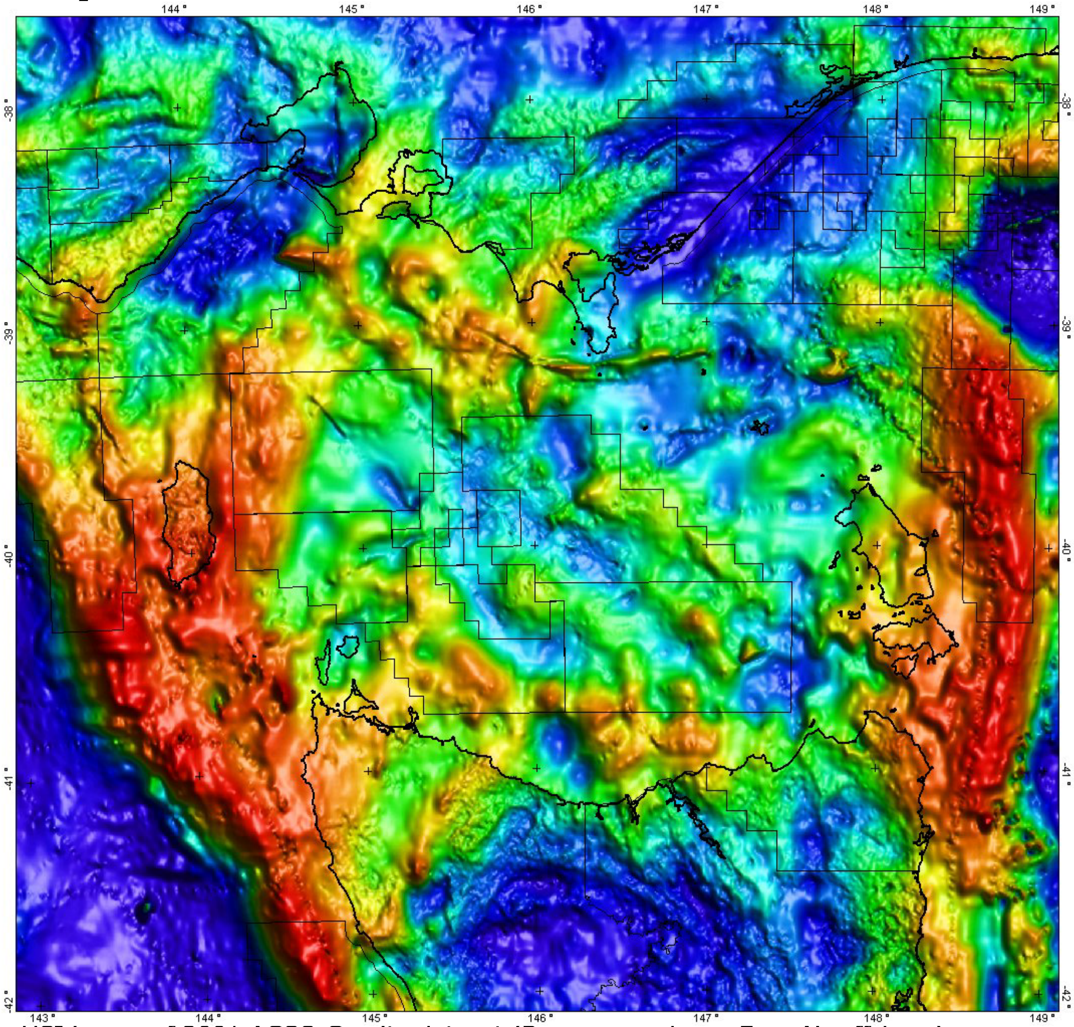
The most important and accurate information provided by magnetic data is the structural fabric of the basement. Major basement structures can be interpreted from consistent discontinuities and/or pattern breaks in the magnetic fabric. Once the structures have been evaluated and combined with those interpreted from the gravity data, a model for the evolution of the basement and overlying basins can be developed.

At least 20 datasets have been stitched and/or mosaiced to construct the above grid (see Appendix 1). All magnetic grids were imaged in ERMapper using a Hue-Saturation-Intensity colour model. Various enhancement filters were applied to resolve the geometry and structure of the basement at depth (see overleaf).

Enhancement Processing of Magnetics



Gravity



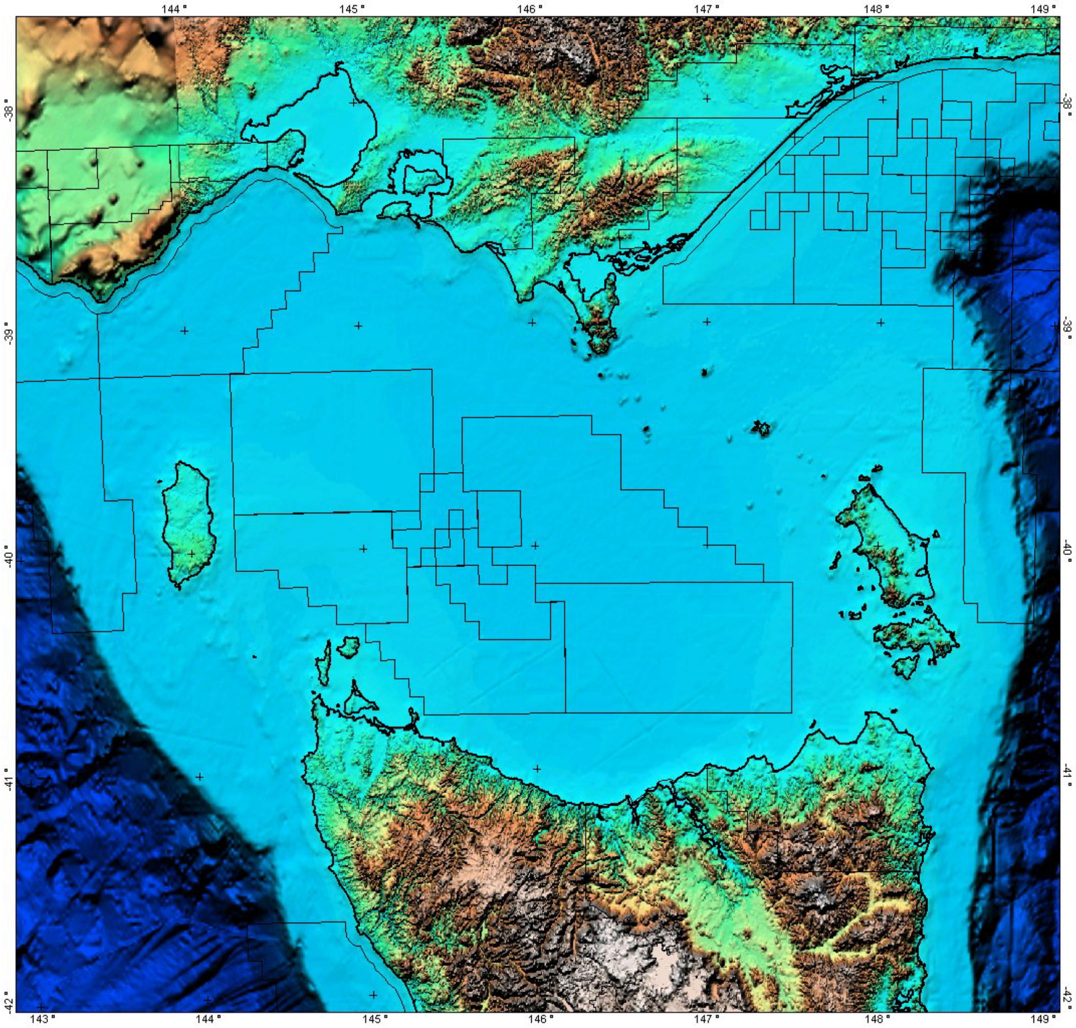
HSI image of 2001 AGSO Gravity dataset (Bouguer onshore, Free Air offshore)

Gravity data is a very important tool for interpreting basins. It maps subtle changes in the Earthís gravitational field caused by variations in the density of the underlying rocks. Although the resolution of this dataset is low (7km spacing), it provides valuable information on the nature of the deeper parts of the crust and mantle beneath the basins. Important intra-basin elements often have an associated gravity signature indicating that each element is related to a deep basement structure.

In order to evaluate the source of the gravity signature, the data must be calibrated with known geology and/or geophysical models. Gravity images show density contrasts within the crust and upper mantle but the source of the contrast is not unique. Thus the nature of each anomaly must be distinguished in this calibration process.

For the Bass Basin study, the new AGSO 2001 National Gravity Grid was imaged in ERMapper using a Hue-Saturation-Intensity colour model. The new AGSO gravity grid is a compilation of onshore survey data, Geosat satellite gravity offshore, and marine shiptrack data.

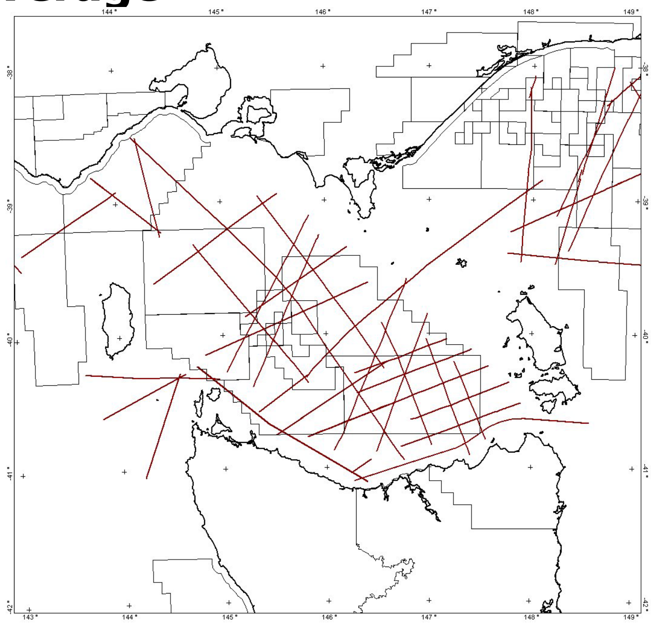
Digital Elevation Model



Digital Elevation Models (DEM's) often show the youngest structures, and any active geological structures. They are widely used for neotectonic analysis. The composition of eroding terrain controls its resistance to weathering, hence DEM's can be used to distinguish different compositional domains.

The Digital Elevation Model (DEM) for the project area shows the topography of Tasmania and southern Victoria, resulting from Cretaceous to Recent uplift. Notably the bathymetry of Bass Strait is very shallow and flat.

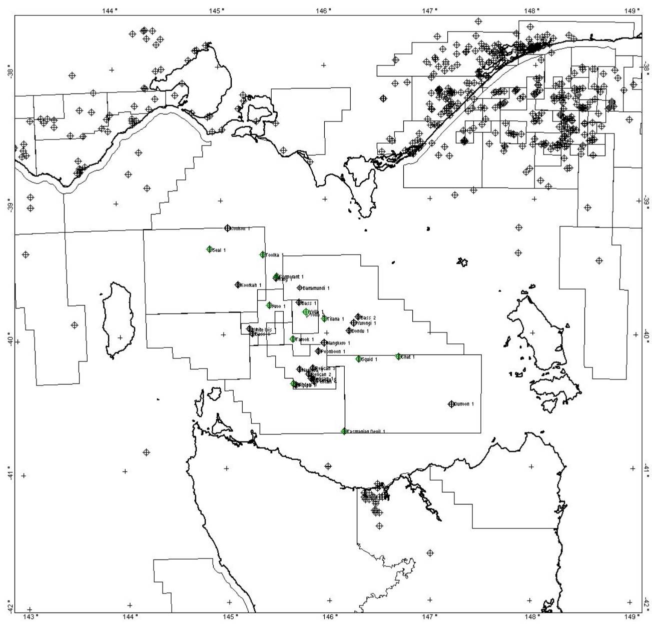
Seismic Coverage



Seismic coverage in the Bass Basin is fairly limited and of variable quality due to abundant volcanics. The top-basement unconformity is generally not clearly imaged.

In this study the limited seismic data shown above have been used as a calibration tool for the depth to basement modeling and the structural interpretation (particularly timing of structural reactivation).

Wells Coverage



Well coverage in the Bass Basin is fairly limited. Importantly, several wells which intersected "unknown" lithologies at TD are interpreted in this study to have intersected basement (e.g. White Ibis 1, Bass 3 and Barramundi 1)

Plate Tectonic Reconstructions

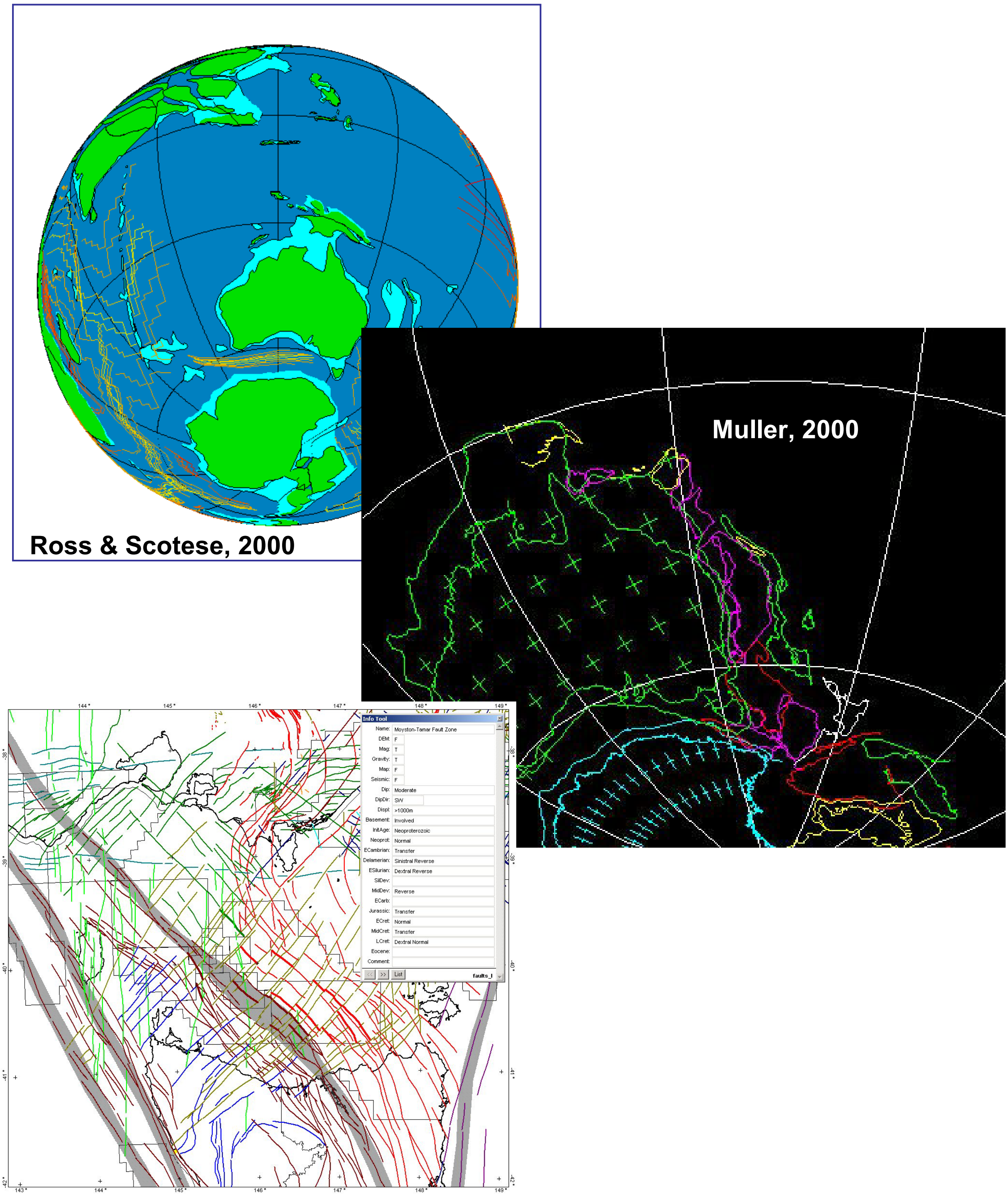
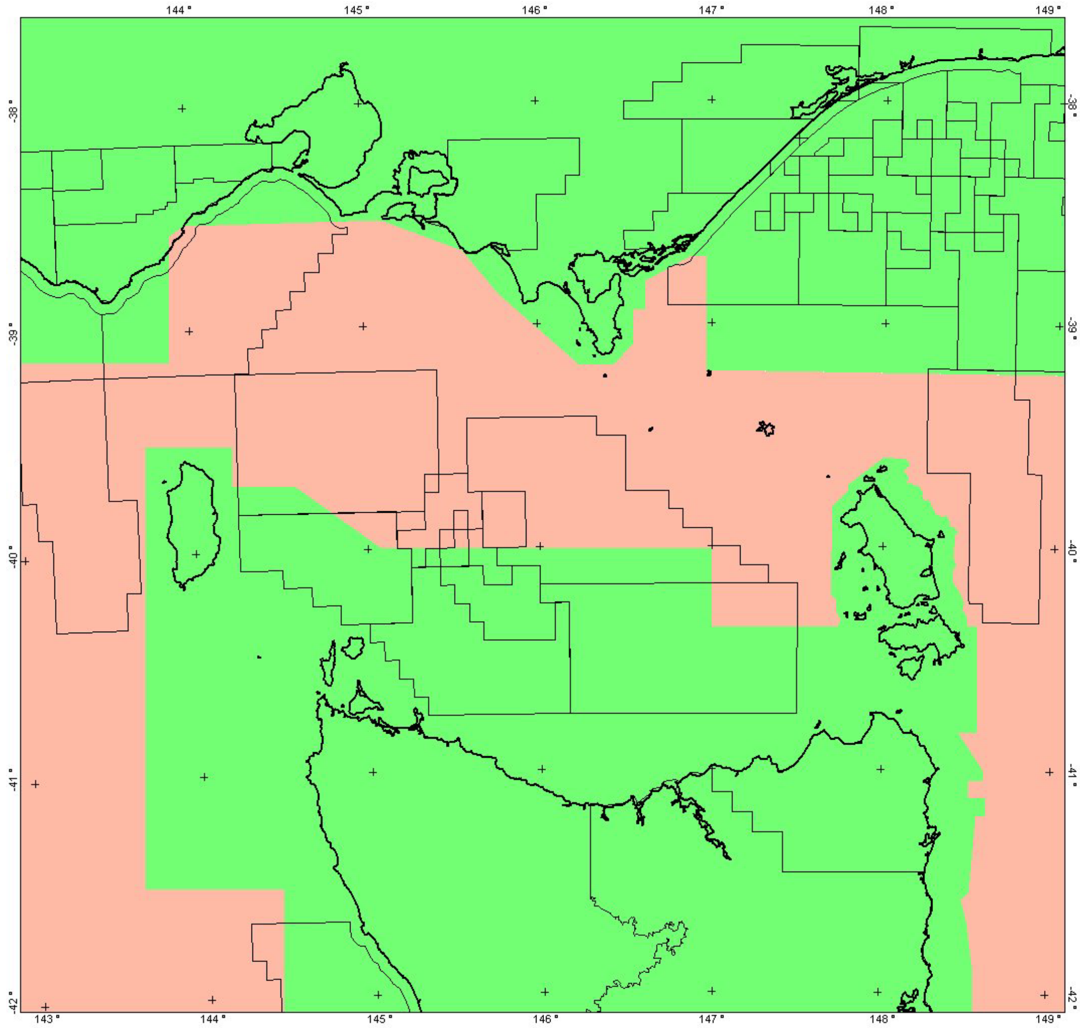


Plate tectonic reconstructions, produced from the PaleoMap project (Ross & Scotese, 2000) and Muller (2000), were used in rate-azimuth analysis and the creation of plate tectonic movies. The reconstructions provided constraints on the interpretation of basement terranes and the timing and kinematics of tectonic events.

Interpretation Confidence



Due to the large differences in data quality (particularly in the magnetic coverage), the confidence levels in the interpretations presented here vary significantly. The above map shows where the interpretations are of relatively low confidence (orange). Aeromagnetic data quality in these areas varies from poor to non-existent. Green areas are covered by relatively recent, high resolution aeromagnetic surveys. See Appendix 1 for magnetic survey information.

Calibration of Potential Field Data

Calibration is a critical process in any potential field interpretation.

In order to extract as much reliable geological information as possible from potential field data, it is critical to calibrate the data. This is done initially using mapped geology or basement well intersections combined with rock property data (e.g. magnetic susceptibility, density). Once identified, mapped geological units can be traced offshore or under sedimentary cover. Knowing the particular geological units provides information about basement composition and allows for much better constrained depth models from magnetic data.

Away from outcrop control, seismic data are integrated (when available) to further constrain the development of a geological model. Basement penetration by wells and deep seismic data are particularly useful in constraining depth-to-basement estimates from the aeromagnetic data.

Why Basement?

The basement of any basin provides the foundation onto which the sediments are deposited. The rheology and mechanical behaviour of the basement controls the geometry and rate of subsidence of the evolving basin. Basement rheology and mechanical behaviour are determined by its composition and structural fabric. Thus it is important to understand basement evolution prior to basin development.

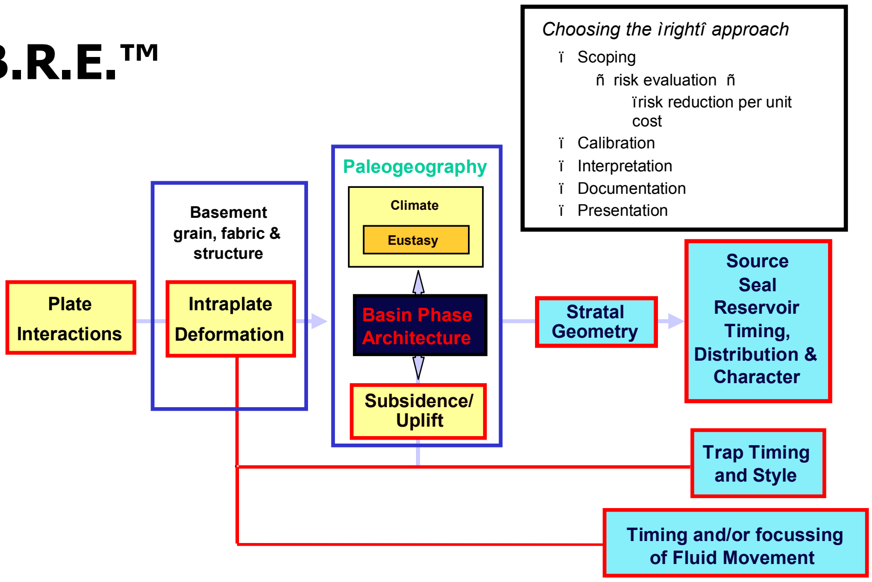
Understanding basement structures allows models to be developed that can predict which structures will reactivate, and how they will move under an applied stress. Using plate tectonic reconstructions, the far-field stress state during past events can be estimated and a kinematic reconstruction produced for each event. Basin sediments deform in response to movements in the basement and to gravity. Knowing how and when the basement moves provides a basis for predicting the most likely locations of depocentres and structures in the sediments.

Hence basement influences:

- basin phase architecture
- source-rock quality and distribution
- heat flow
- migration focusing, pathways and timing
- trap timing, distribution, type, integrity & size
- sediment supply and stratal geometry
- reservoir, seal quality & distribution

Systematic Approach to Basin Resource Evaluation

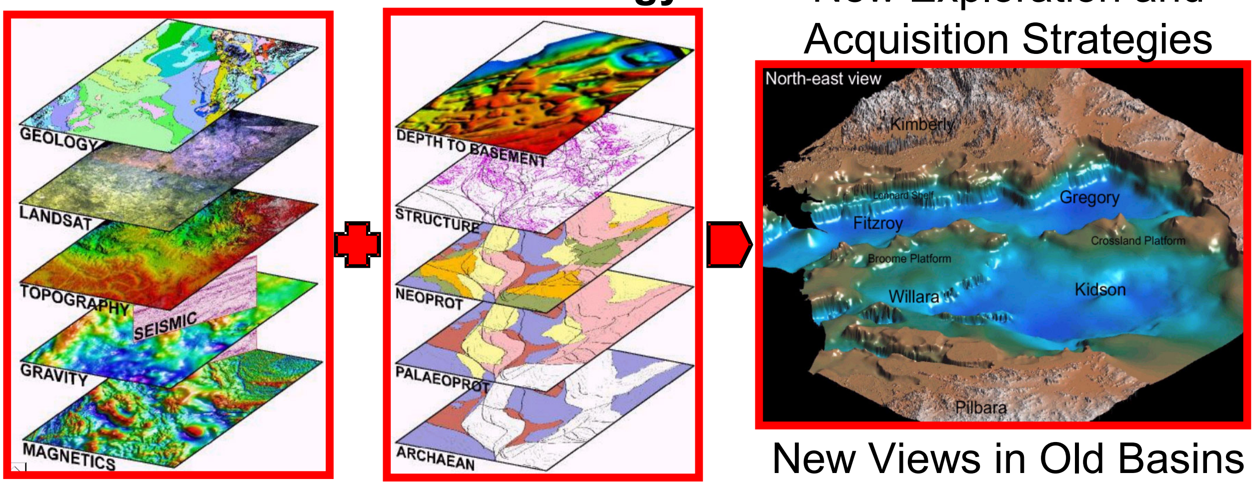
S.A.B.R.E.™



The methodology used to develop a comprehensive structural model relies on the integration of all available geological information. Individual datasets alone can be ambiguous and when isolated often produce poorly constrained interpretations. Through integration, the model can be tightly constrained. Integration provides the means with which to calibrate each dataset to the other.

Basement Character and Petroleum Systems

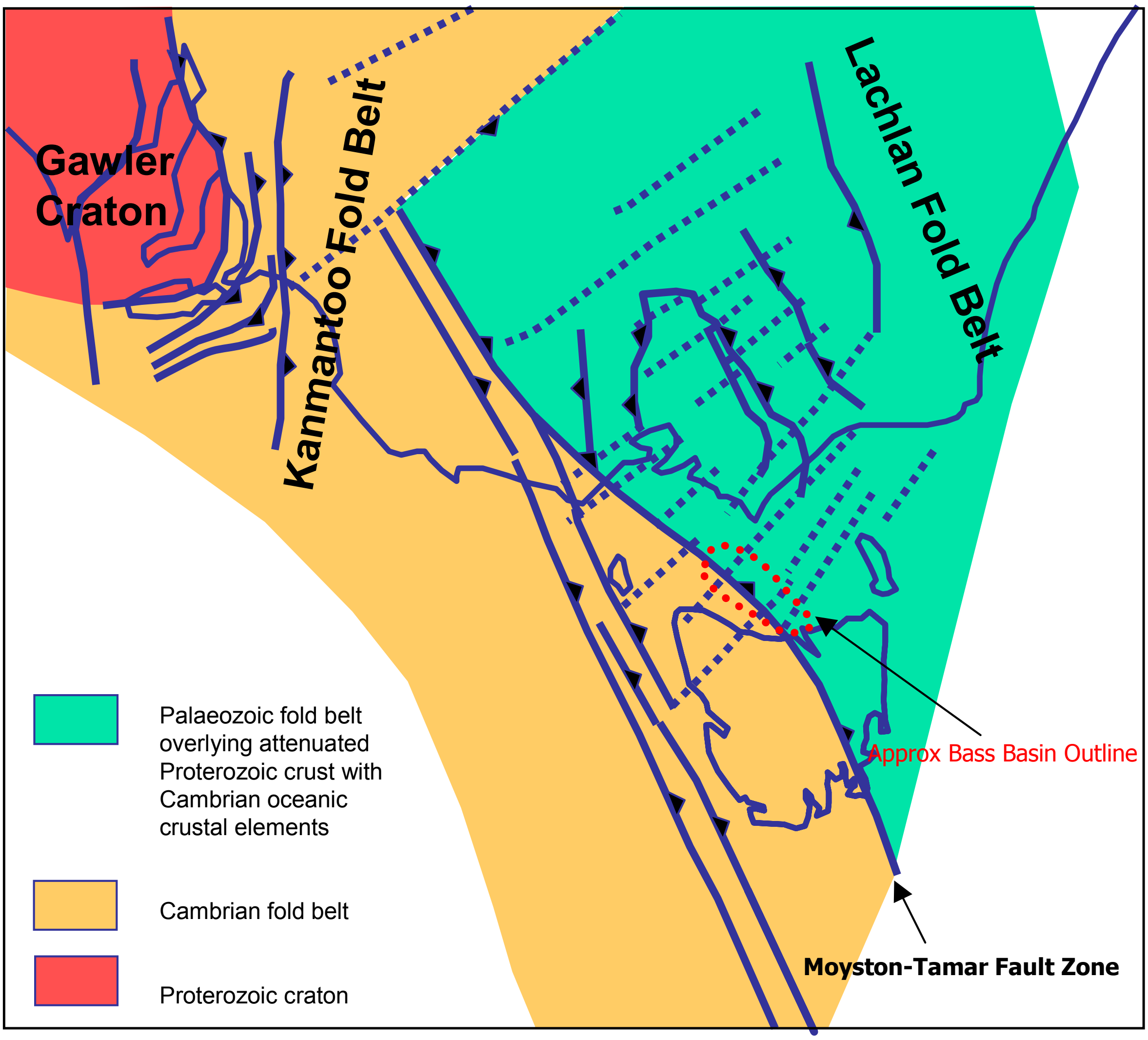
Old Data | **Good Geology** | New Exploration and Acquisition Strategies



New Technology | Bottom-up | New Views in Old Basins

Efficient and Effective Exploration

Basement Geology of the Bass Basin



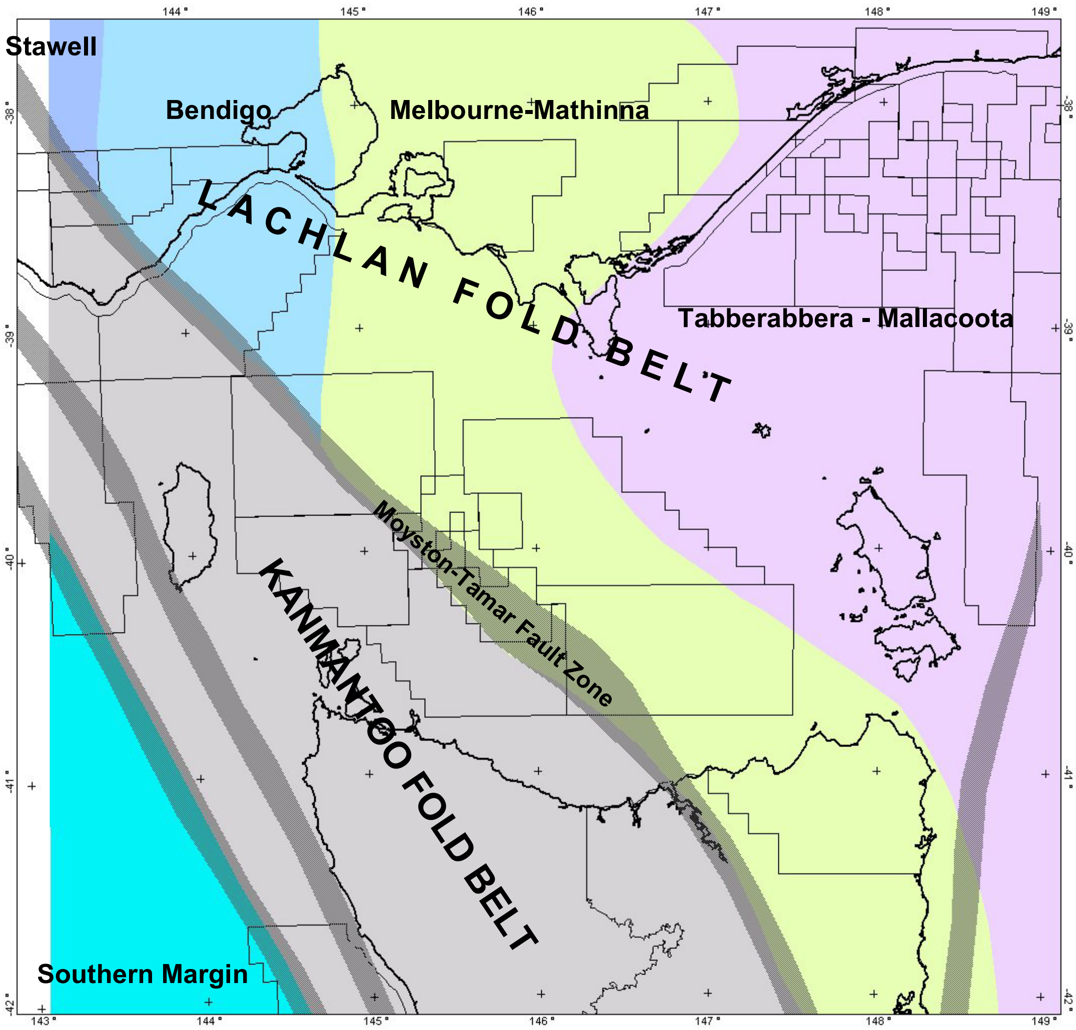
Prior to this study, basement in Bass Strait was very poorly understood. The basement "connection" between Tasmania and mainland Australia had never been adequately resolved. A new model is presented here which provides a simple solution to this enigmatic problem. This model has largely been derived using a combination of the new 2001 AGSO National Gravity Grid and magnetic data reprocessed during this project (datasets unavailable to previous workers).

Our interpretation shows that the western part of Tasmania is part of the greater Kanmantoo Fold Belt; a Cambro-Ordovician mobile belt containing Neoproterozoic-Ordovician sediments and volcanics. The eastern part of Tasmania is part of the Silurian-Carboniferous Lachlan Fold Belt. The Kanmantoo and Lachlan Fold Belts are separated by the Moyston-Tamar Fault Zone; a major east-dipping structure.

The contrasting basement terranes and the structures within and between them were a first-order control on the evolution of the Bass Basin.

This report outlines the basement composition, structure, terranes and depth, and the influence these have on basin evolution and character.

Basement Terranes



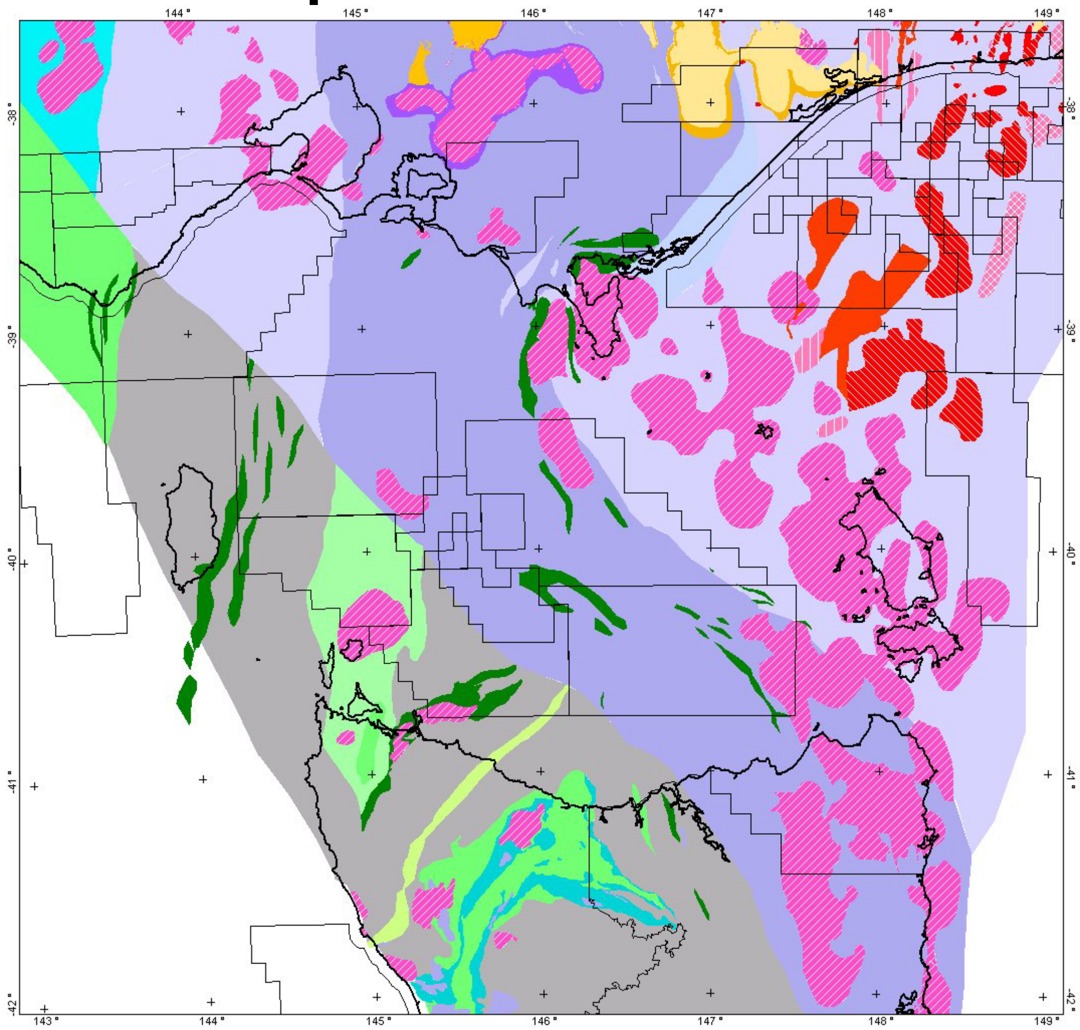
The Bass Basin overlies two key basement terranes: the Kanmantoo and Lachlan Fold Belts. Cambrian platform sequences, turbidites and volcanics were deposited and deformed on the extended Proterozoic margin of Gondwana, forming the Kanmantoo Fold Belt.

The Paleozoic Lachlan Fold Belt consists of ~N-S trending zones which overlie attenuated Proterozoic crust with Cambrian oceanic crustal elements. The fabric of the Lachlan is controlled largely by inherited crustal elements formed during Cambrian extension and contraction of the Proterozoic continental margin. Structures with each terrane are generally "thin-skinned", with major basement-involved, "thick-skinned" structures forming terrane boundaries.

The boundary between the Kanmantoo and Lachlan Fold Belts is the Moyston-Tamar Fault Zone. Both the Moyston Fault (Victoria) and Tamar Fracture Zone (Tasmania) are well known to represent the "edge" of thick Neoproterozoic-Cambrian crust in eastern Australia, however this is the first time they have been recognized to be part of the same major structure/terrane boundary.

The Moyston-Tamar Fault Zone/Terrane Boundary has provided a first order control on the development of the Bass Basin.

Basement Composition



Late Devonian-Carb sediments

Late Devonian volcs

Early Devonian volcs + sediments

Upper Devonian metamorphic aureole

Siluro-Dev seds

Ord metamorphics

Ord-Early Sil seds

Cambrian greenstone belts

Latest Neoprot sediments

Neoproterozoic (meta)sediments

Granites

mid to Upper Dev

Lower Devonian

Siluro-Devonian

Lower Silurian

The basement composition beneath and adjacent to the Bass Basin reflects the two underlying basement terranes; the Kanmantoo and Lachlan Fold Belts. Southwest of the Moyston-Tamar Fault Zone (MTFZ), Neoproterozoic sediments are unconformably overlain by Cambrian-Ordovician sediments and volcanics. Northeast of the MTFZ, the Bass Basin is underlain by Siluro-Devonian sediments of the Melbourne-Mathinna Zone. Slivers of Cambrian volcanics have been exhumed along major thick-skinned basement thrusts.

Basement Structure - Overview

Basement structures are key reactivation zones during basin formation. The following basement structures have been interpreted during this project:

- Faults/shear zones
- Fabric/grain/foliation
- Deep crustal fracture zones
- Transfer/accommodation zones

These structures have been interpreted using the following data sources:

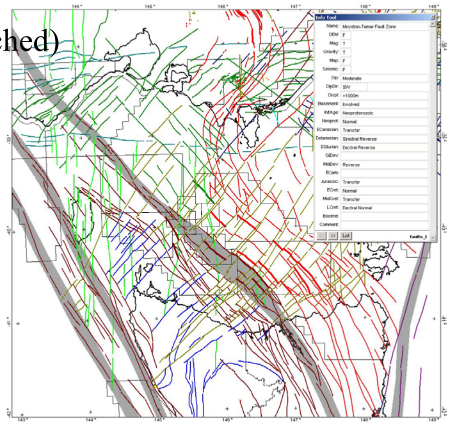
- Mapped faults
- Magnetic anomalies & discontinuities
- Gravity anomalies & discontinuities
- DEM trends & breaks
- Seismic basement-involved faults

The history of the structures is quantified using the following criteria and calibration:

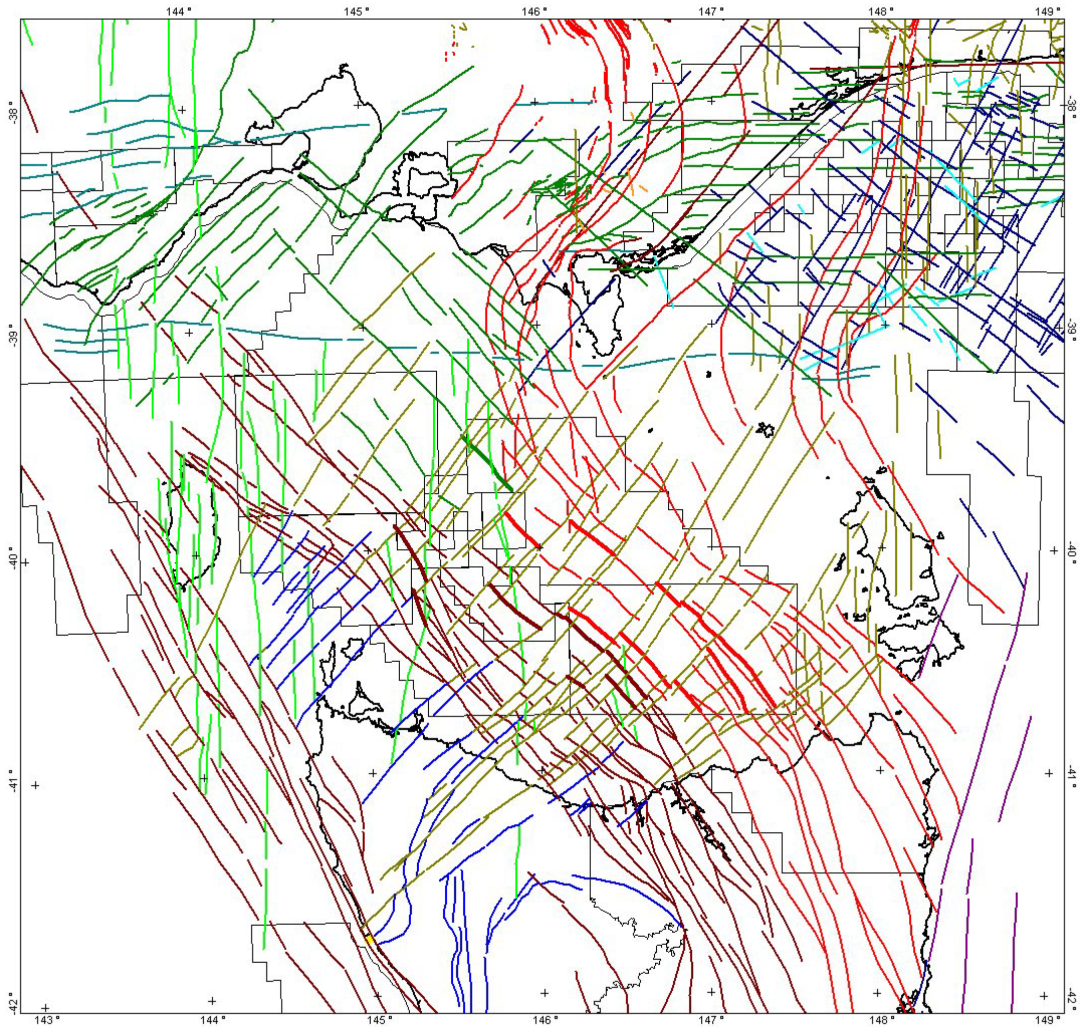
- Structural superposition
- Age of strata displaced
- Relationship to intrusive bodies
- Consistency of fault kinematics to regional paleo-stress regimes and plate movements
- Correspondence to: mapped structures, known movement history

In the GIS, the faults are all attributed by:

- Source (magnetics, gravity, DEM, map etc)
- Orientation
- Displacement
- Basement character (involved or detached)
- Initiation age
- Reactivation history



Basement-Involved Faults

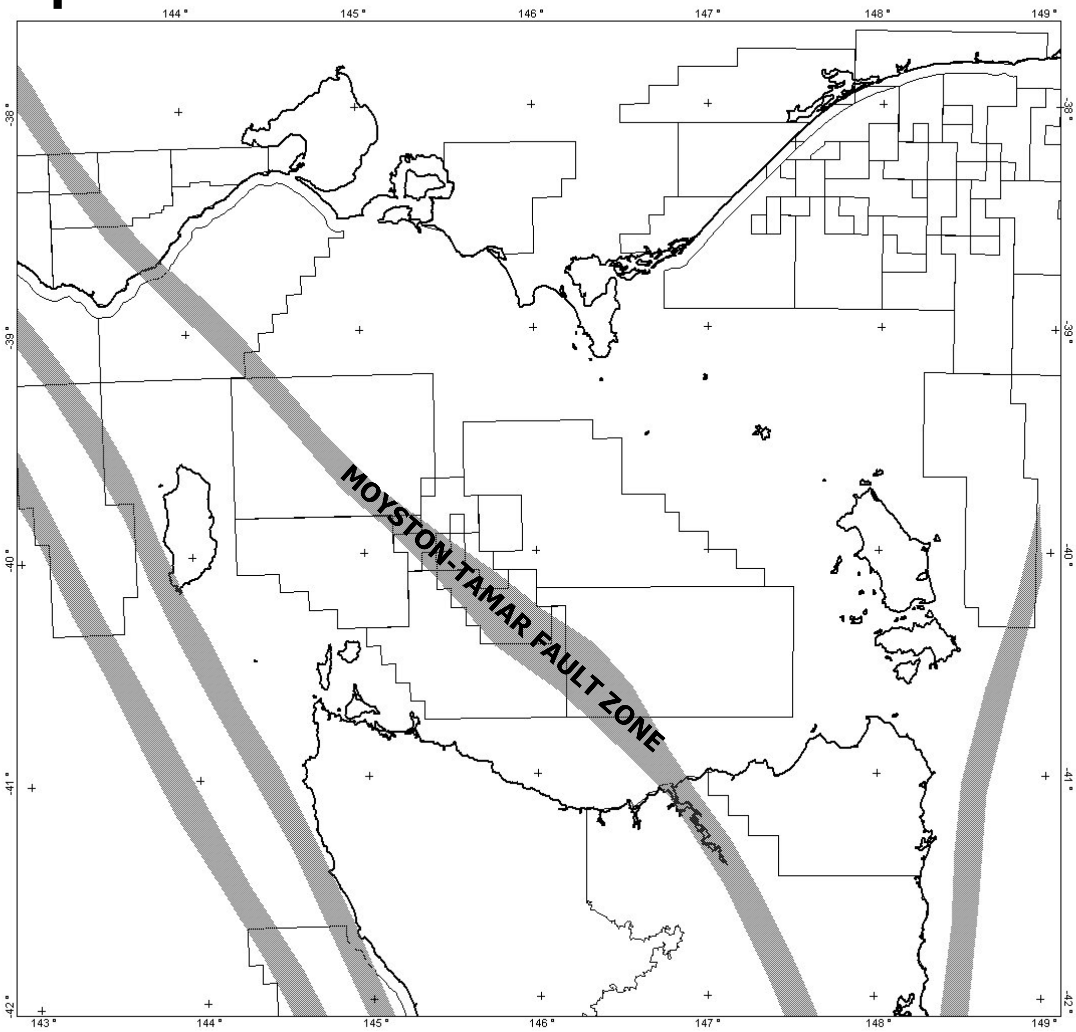


All interpreted basement-involved faults in the Officer Basin are presented here in colours representing initiation age:

- Neoproterozoic
- Early Cambrian
- Cambro-Ordovician
- Early Silurian
- Mid Devonian
- Early Carboniferous

All faults have been extensively attributed according to their reactivation history, data sources, orientation, displacement etc.

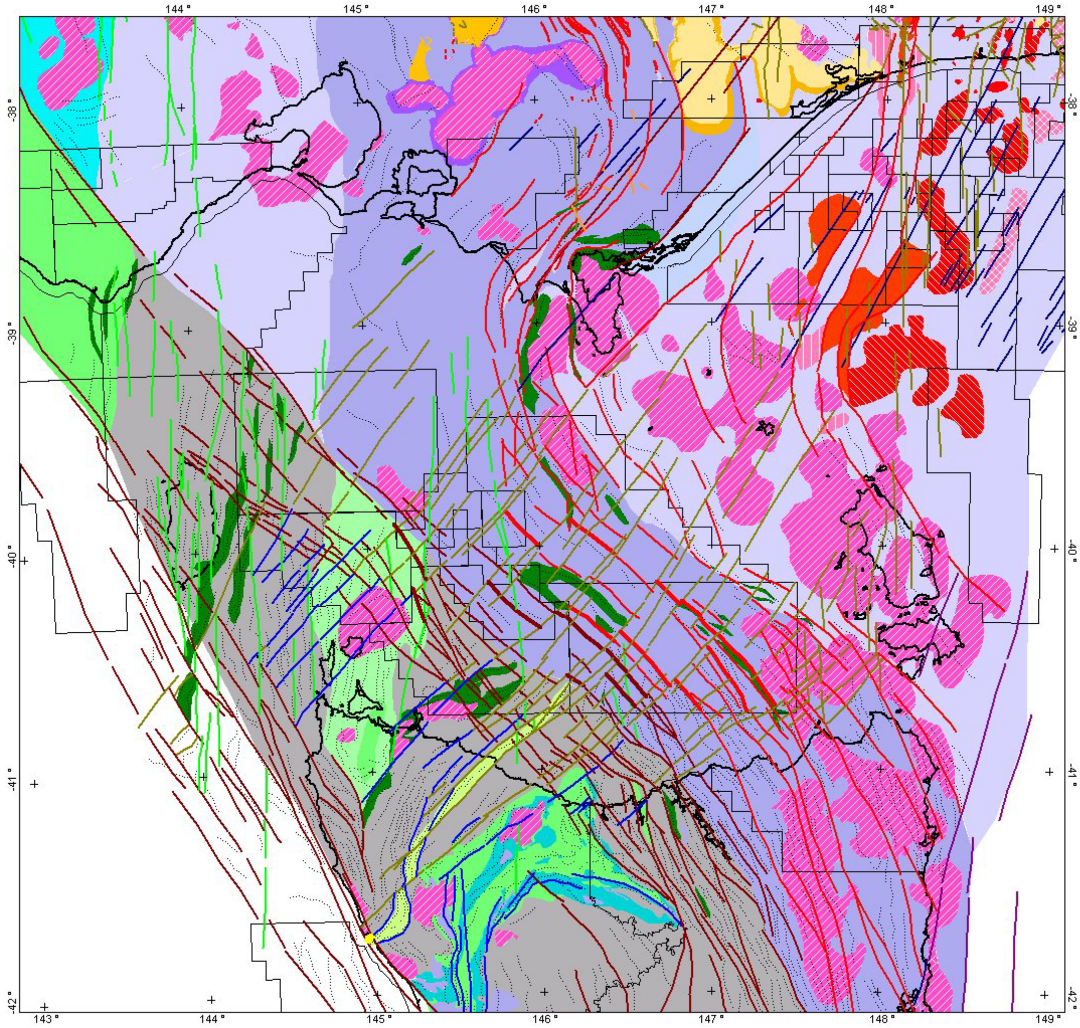
Deep Crustal Fracture Zones



Deep crustal fracture zones are seldom directly mappable in basins. They are deep seated (possibly mantle-derived), ancient zones of crustal weakness that directly or indirectly influence the subsequent development of structures and basins. They are often repeatedly reactivated. Often they coincide with terrane boundaries.

One deep crustal fracture zone underlies the Bass Basin ñ the Moyston-Tamar Fault Zone.

Proterozoic Basement Deformation



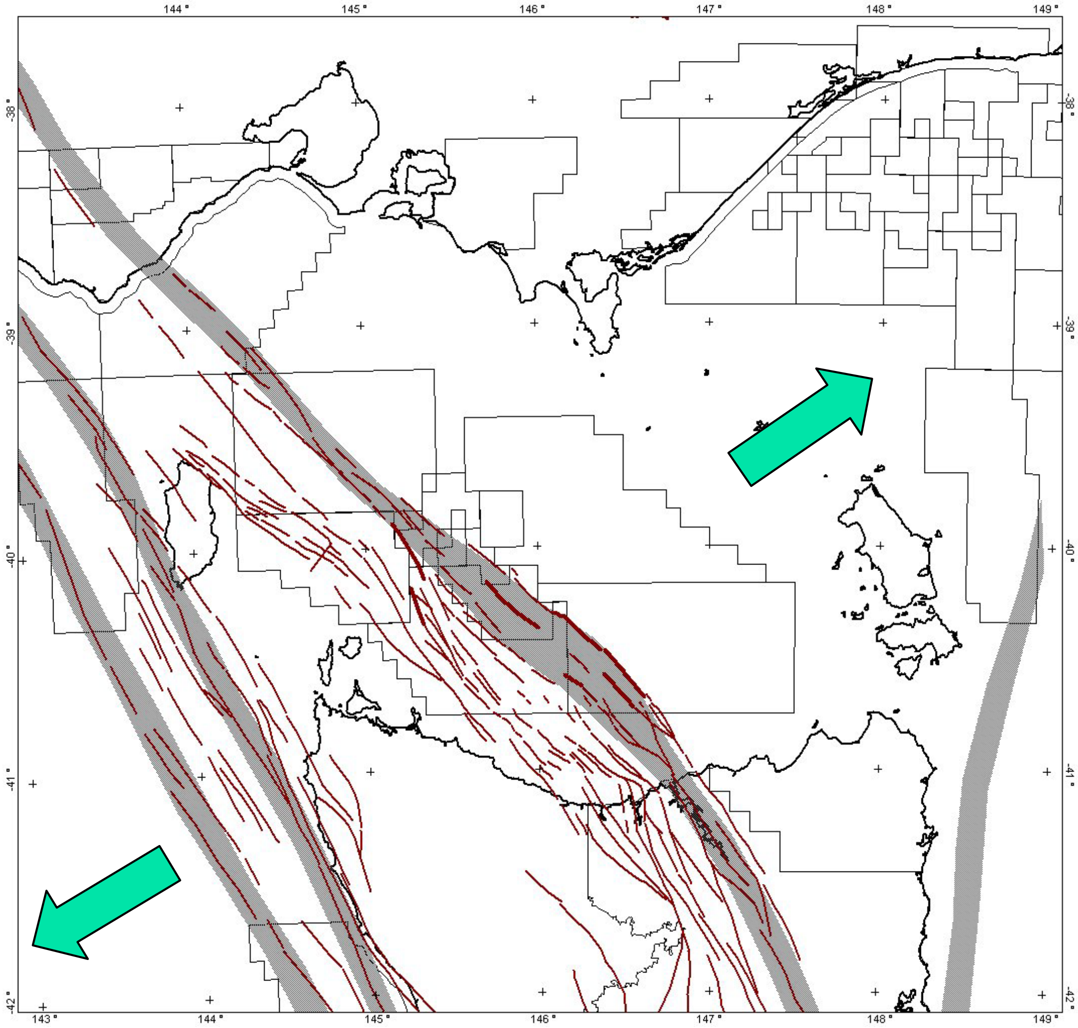
Basement terranes in the Bass Strait region have undergone a complex history spanning the Proterozoic to the late Paleozoic. The entire area is interpreted to be underlain by highly extended Paleo-Mesoproterozoic continental crust. Large scale structures which evolved during extension of the Proterozoic crust have exerted significant influences on the subsequent structural evolution of the Kanmantoo and Lachlan Fold Belts.

Both the Kanmantoo and Lachlan Fold Belts were formed during the evolution of the eastern Australian active margin during the late Neoproterozoic to late Paleozoic. Seven major tectonic "events" have been identified:

1. Neoproterozoic Extension
2. Early Cambrian Extension
3. Cambro-Ordovician Orogeny
4. Early Silurian Deformation
5. Late Silurian-early Devonian Deformation
6. Mid-Devonian Deformation
7. Early Carboniferous Deformation

These events are outlined in the subsequent pages.

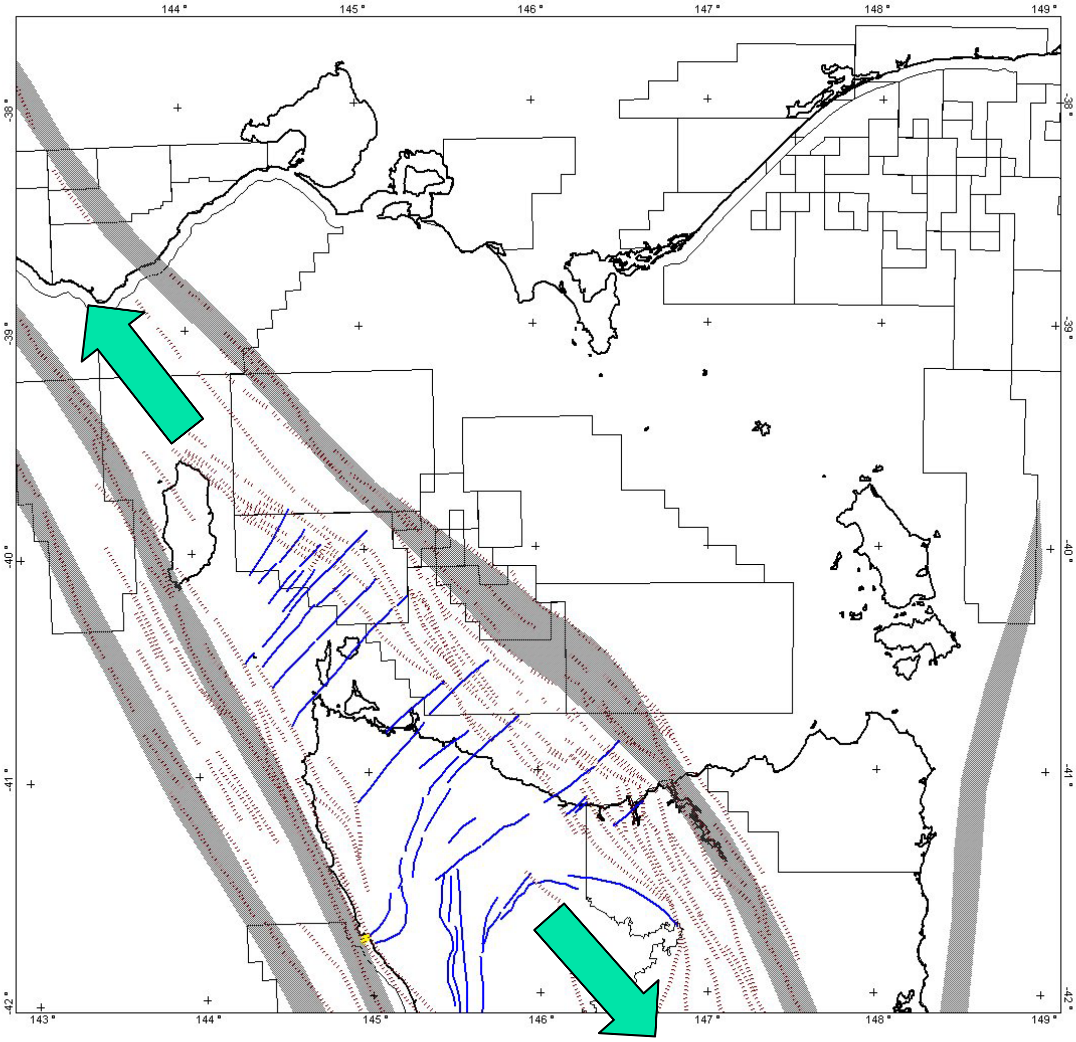
Neoproterozoic Basement Evolution



Intracratonic rifting in Rodinia was initiated at ~800Ma by rapid NE-SW extension resulting in the NW trending Gairdner Dyke Swarm. Subsequent extension between North America and Australia exploited these structures (some of which constitute the Tasman Line), resulting in the deposition of thick Neoproterozoic sedimentary sequences in a belt that included the Adelaide Geosyncline, what is now western Tasmania and the Ross Orogen in Antarctica.

Major NW linear structures in western Tasmania and western Victoria are interpreted to have evolved during this Neoproterozoic extension. Therefore the Moyston-Tamar Fault Zone probably dates back to the early Neoproterozoic.

Early Cambrian Basement Evolution

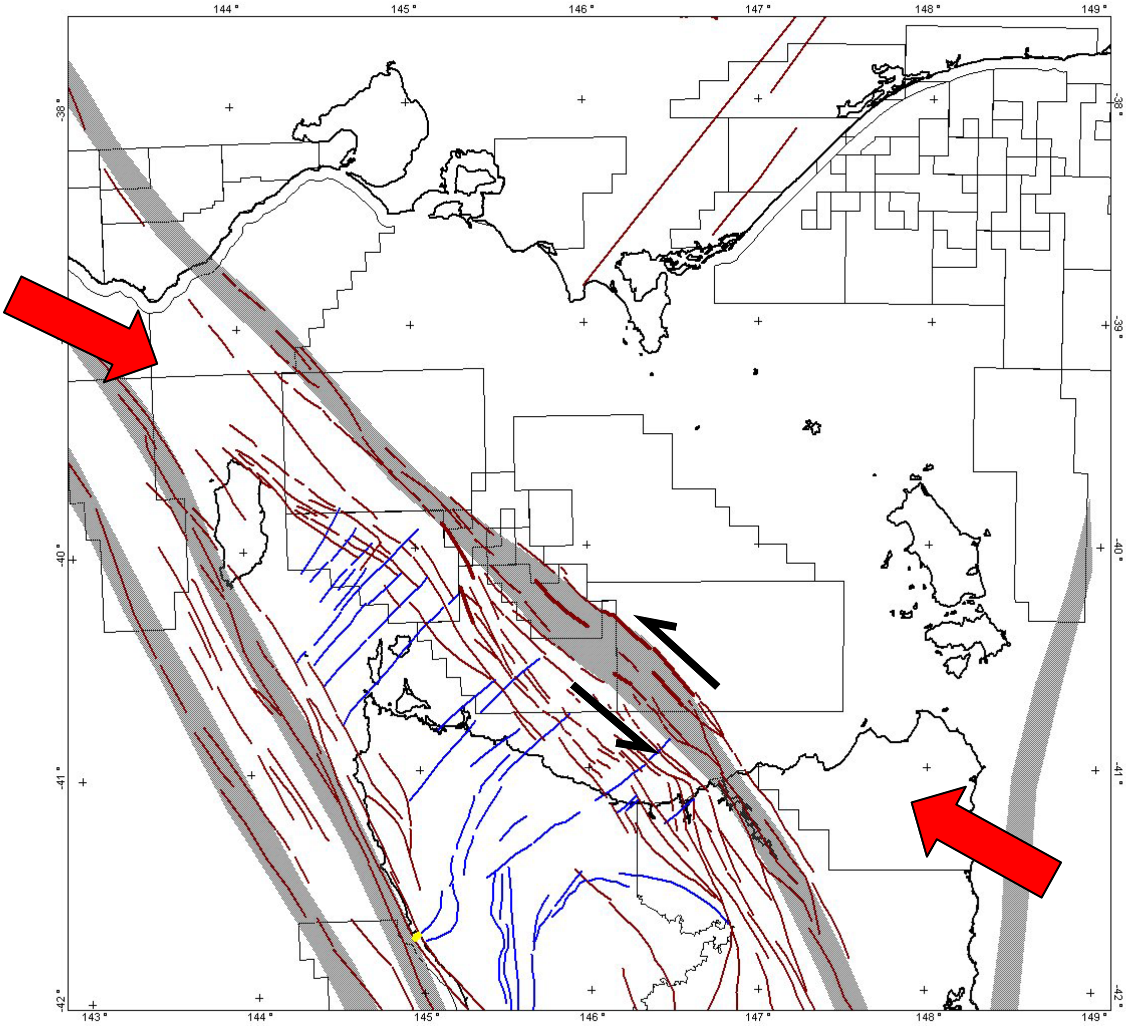


Early Cambrian extension in eastern Australia was caused by ongoing rifting and eventual breakup between Australia & North America along the Tasman Line. In the early Cambrian this extension was oriented ~NW-SE. Most of the extension was accommodated to the east of the Tasman Line on structures in the Lachlan Fold Belt.

In the Kanmantoo Fold Belt, Early Cambrian extension in ~NE trending rifts resulted in the deposition of thick sedimentary sequences and volcanics (including the Mt Reed Volcanics). Similar Cambrian sequence are interpreted to underlie most of the Lachlan Fold Belt.

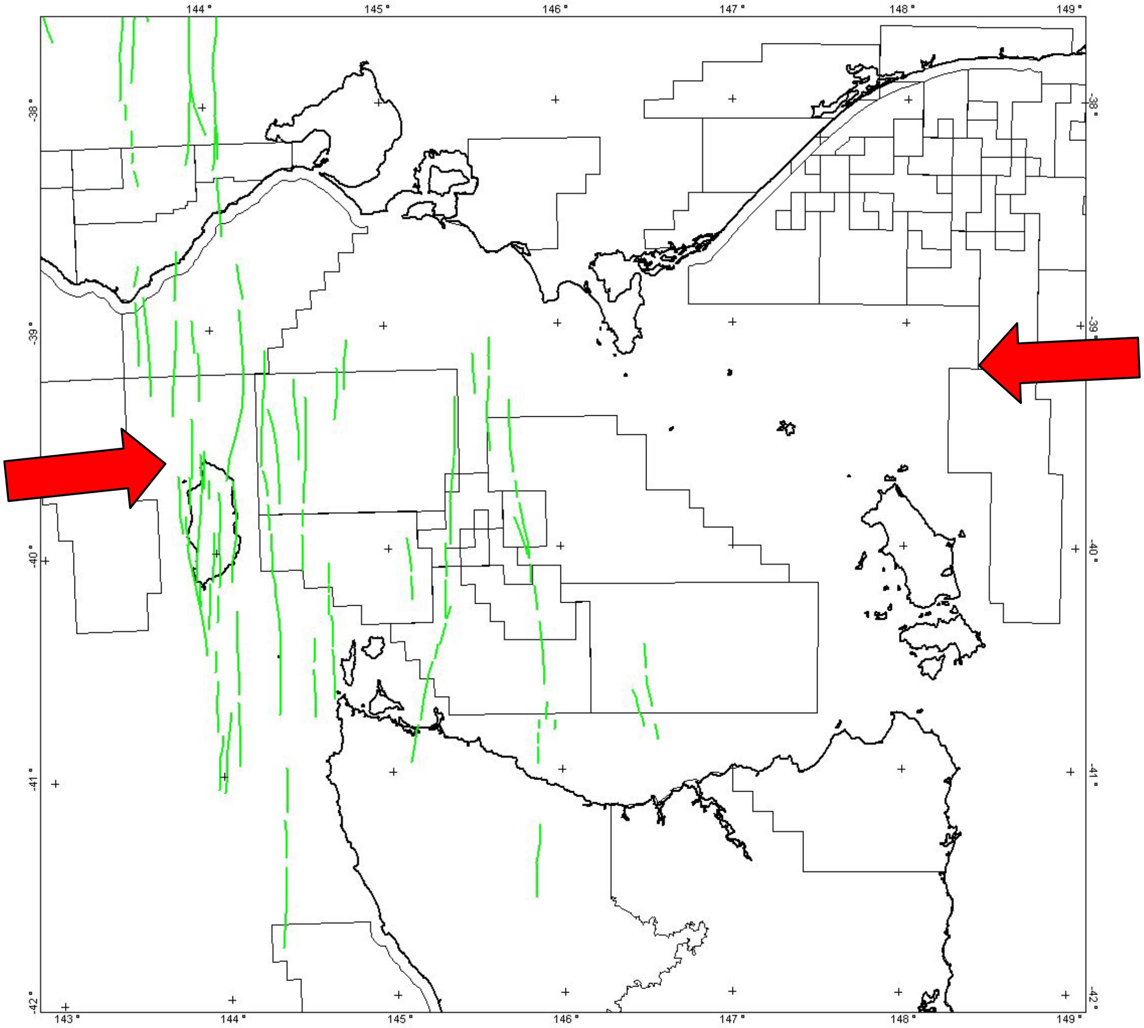
The resultant fracture zones and variation in crustal thickness produced during the Neoproterozoic and early Cambrian extension events define the principal basement architecture that has significantly controlled the location and nature of all subsequent Palaeozoic and Mesozoic contractional and extensional events.

Cambro-Ordovician Basement Evolution



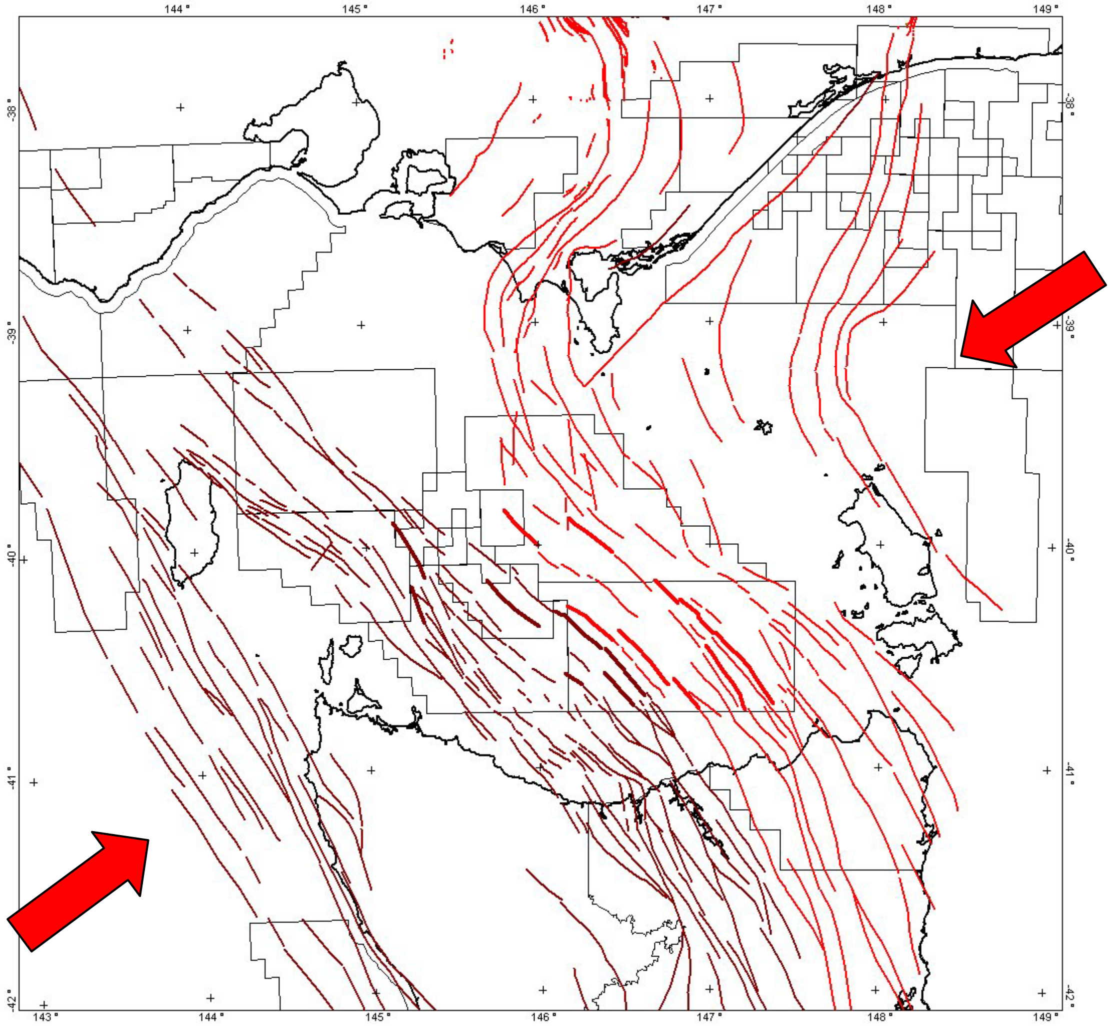
The Cambro-Ordovician Delamerian Orogeny (~520-480Ma) caused extensive ~WNW-directed deformation in the Adelaide and Kanmantoo Fold Belts, and presumably beneath the Lachlan Fold Belt. Obducted Cambrian oceanic crustal elements and island arc fragments (preserved in the Victorian greenstone belts), together with Cambrian passive margin sediments deposited on the extended Proterozoic craton margin, were deformed and variably metamorphosed at this time. After initial deformation, post-collisional medium- to high-K calc-alkaline andesitic volcanic arcs formed on the active continental margin. Thick Late Cambrian-Ordovician quartz-rich turbidite deposits overlie the arc sequences in parts of the Lachlan Fold Belt.

Late Silurian-Early Devonian Basement Evolution



During the Early Devonian (Bowning) deformation, lateral compression resulted in meridional folding and low-grade regional metamorphism of the Ordovician and Siluro-Devonian sedimentary sequences. The contraction occurred at about 410 Ma in the back-arc region of the Silurian "Calliope Arc" (Veevers, 2000) with a W-directed principal stress direction (eg. Stuart-Smith et al., 1992). The deformation is responsible for the dominant meso- and microscale structural grain of the basement Ordovician and Silurian metasediments in the Bendigo and Stawell Zones. These N-S trending structures are interpreted here to extend south into Bass Strait.

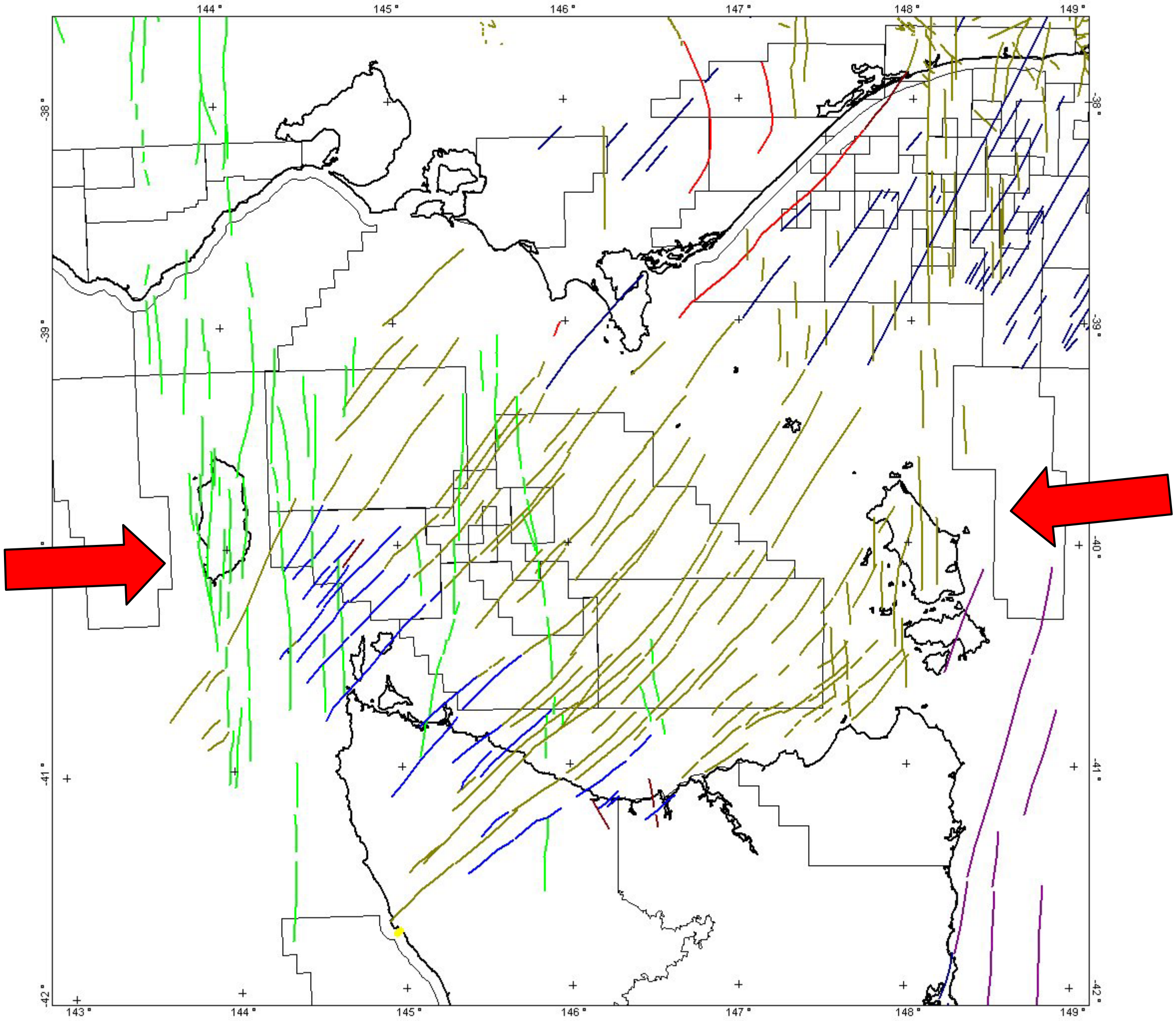
Mid-Devonian Basement Evolution



Widespread folding closely linked to faulting occurred during late Early to mid Devonian times throughout most of the Lachlan Fold Belt and the eastern-most parts of the Kanmantoo Fold Belt. The (Tabberabberan) deformation, with an indicated NNE- to NE-directed principal stress (eg. Glen, 1990) was a short-lived event between 390 and 380 Ma (Vandenberg, 1999). The deformation followed an episode of Early Devonian rifting, felsic volcanism and granite intrusion, and was associated with contraction and foreland thrust loading to the west of a volcanic arc developed on an oblique convergent paleo-Pacific margin (Veevers, 2000).

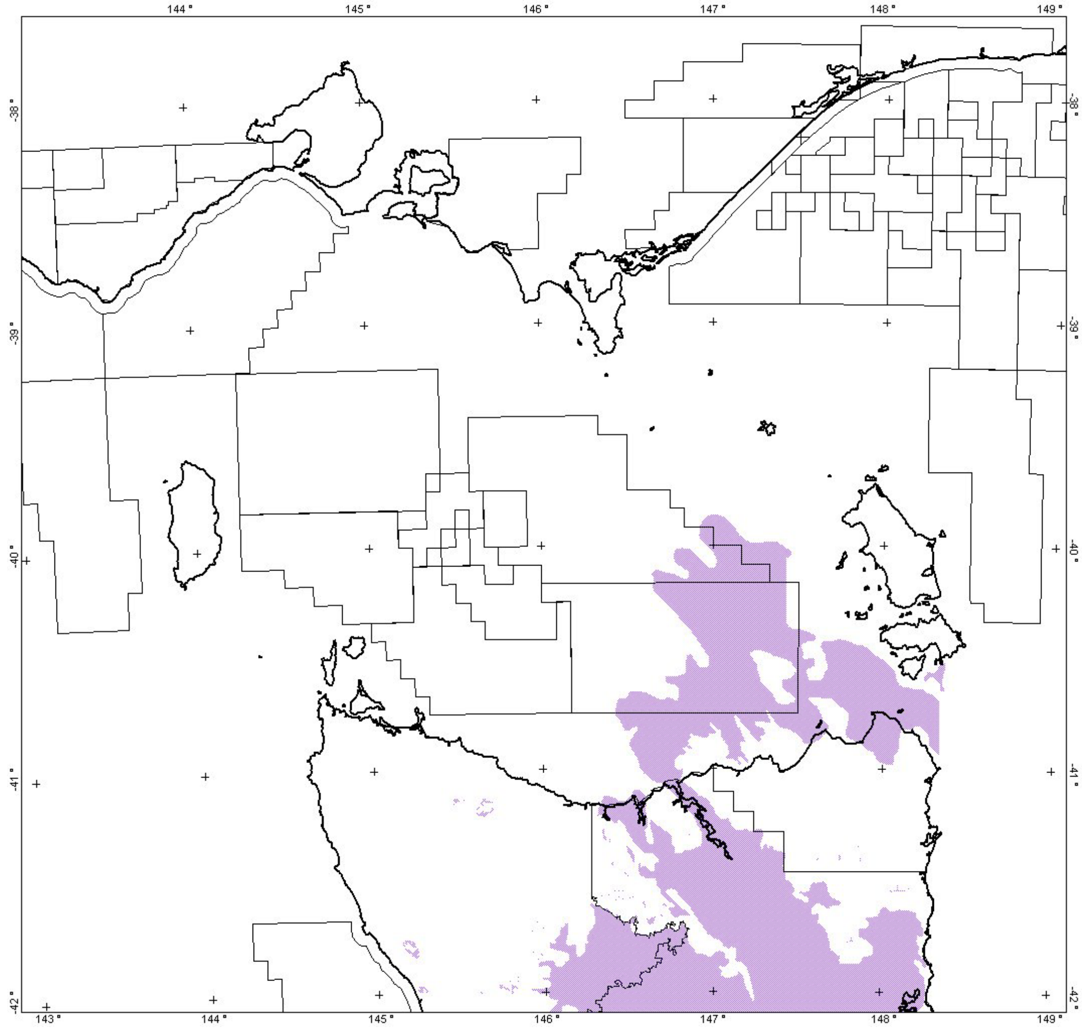
Curvilinear Tabberabberan meridional-trending folds and reverse faults form the dominant structures of the basement in the northwestern part of the study area. This zone wraps around a more rigid ?Proterozoic crustal block (the "Melbourne Zone") covered by a continuous sequence of Ordovician to early Mid-Devonian sediments. The margins of the underlying crustal block have largely focused deformation, in particular, the Mid-Devonian event which was the first to affect much of the area. East of the Melbourne zone, in both onshore and offshore areas, reverse faulting was primarily linked to reactivated margins of Early Devonian rift margins

Early Carboniferous Basement Evolution



During the Early Carboniferous (Kanimblan) deformation event, renewed lateral compression in eastern Australia was associated with an adjacent magmatic arc, located at the convergent paleo-Pacific margin of the Lachlan Fold Belt (Collins & Vernon, 1992). The deformation, at about 345 Ma (Veevers, 2000), resulted in the regional formation of new conjugate strike-slip faults and some reverse reactivation of N-trending Early Silurian and Siluro-Devonian faults. In the Bass Strait region, major NE trending dextral strike slip faults formed. The strike-slip zones terminate in places against N-trending reverse faults that displace Upper Devonian sediments.

Early Jurassic Igneous Rocks

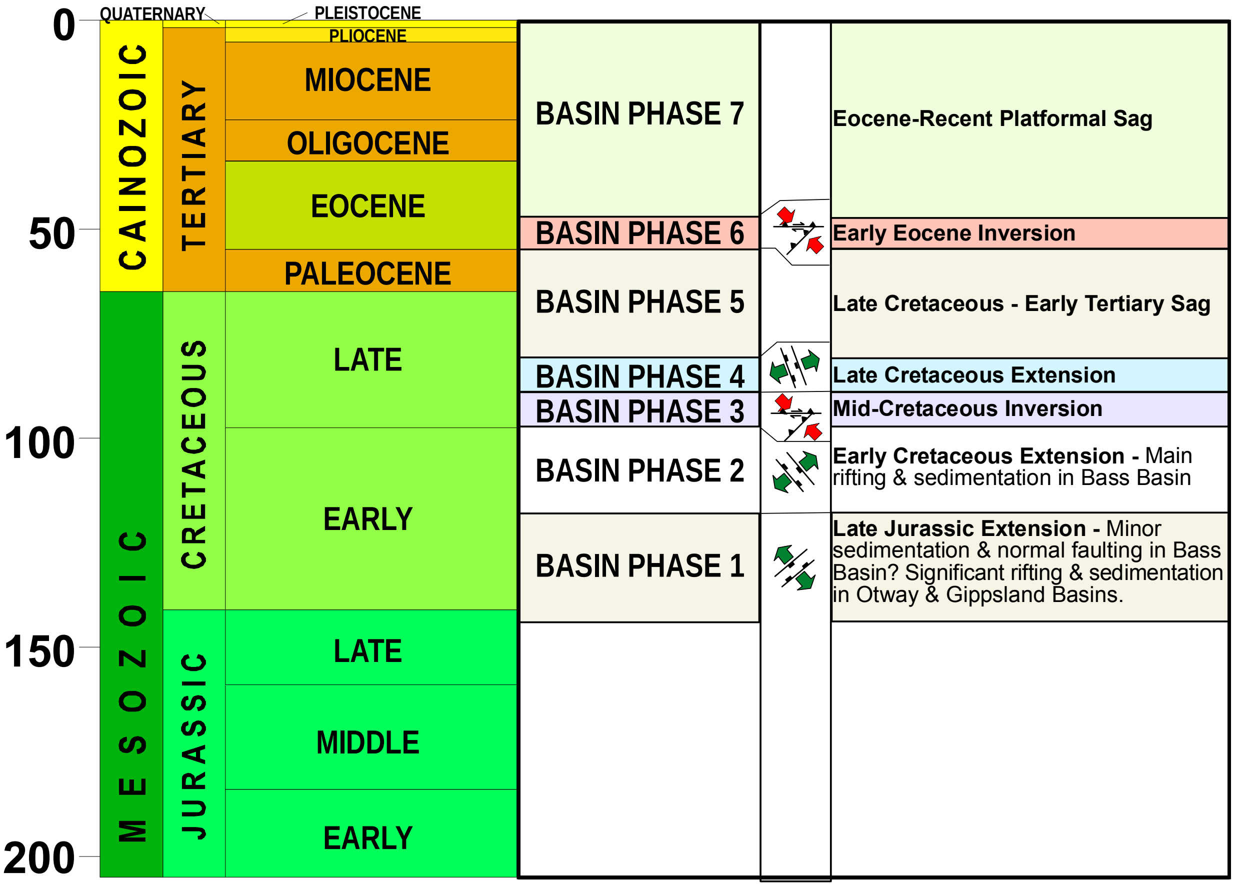


Large volumes of dolerite and basalt were emplaced/extruded into late Triassic sediments at ~174Ma (Burrett & Martin, 1989), covering over half the surface area of Tasmania and parts of Bass Strait. These units form economic and magnetic basement in the eastern part of the Bass Basin.

Basin Evolution

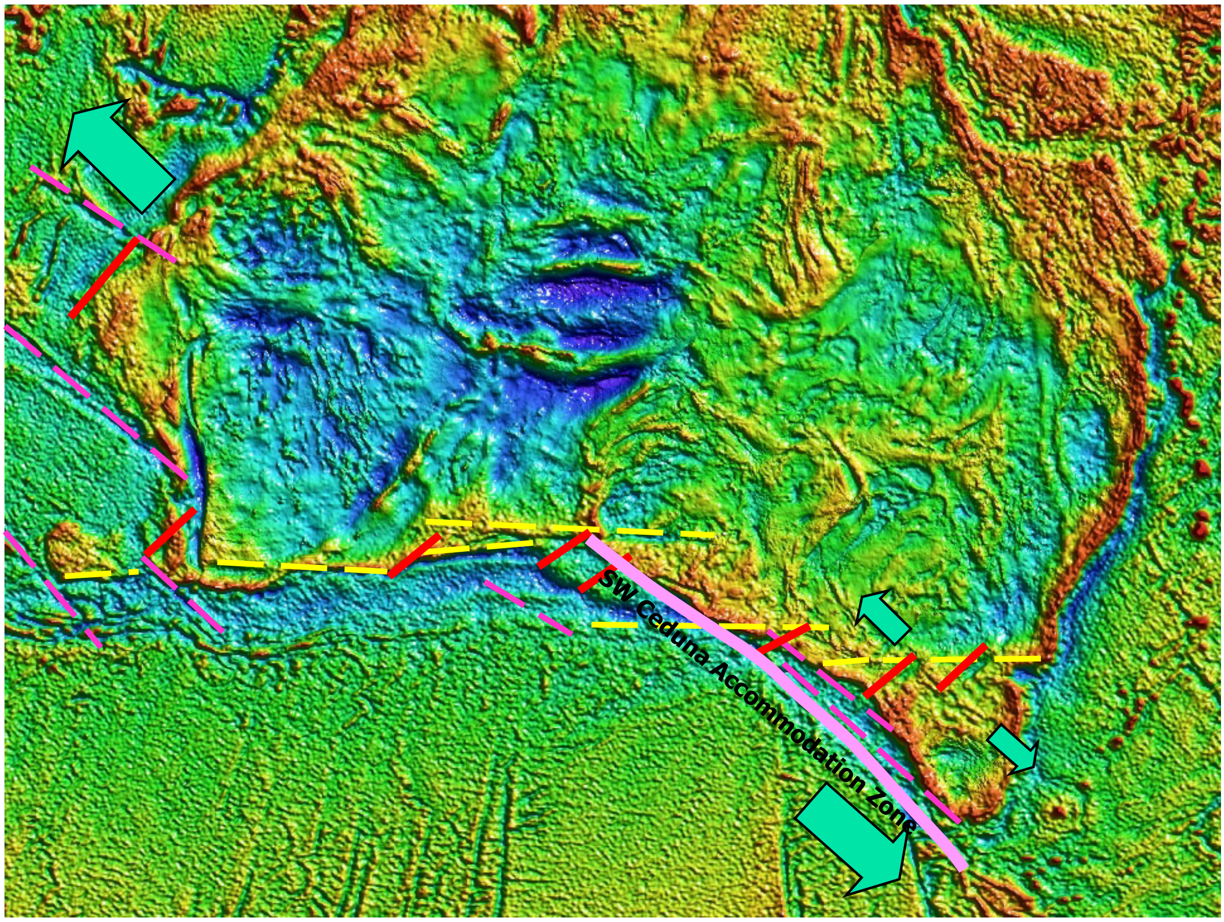
The present-day geometry of the Bass Basin is the result of the superposition of 7 tectonic "events" or basin phases spanning the Jurassic to Recent. These events/basin phases represent the effects of the breakup of Gondwana on the Bass Strait region.

The following chart details the tectonic history of the Bass Basin:



Stresses operating during each basin phase caused reactivation of basement structures and reactive fabrics, as well as the development of new structures. Understanding the kinematics of each tectonic event allows a predictive model for structural reactivation to be applied to the interpreted faults from fault history data calibrated with geological observations (e.g. seismic, maps), event maps for each basin phase have been constructed. The following pages show our interpretation of the structural evolution of the Bass Basin and surrounds.

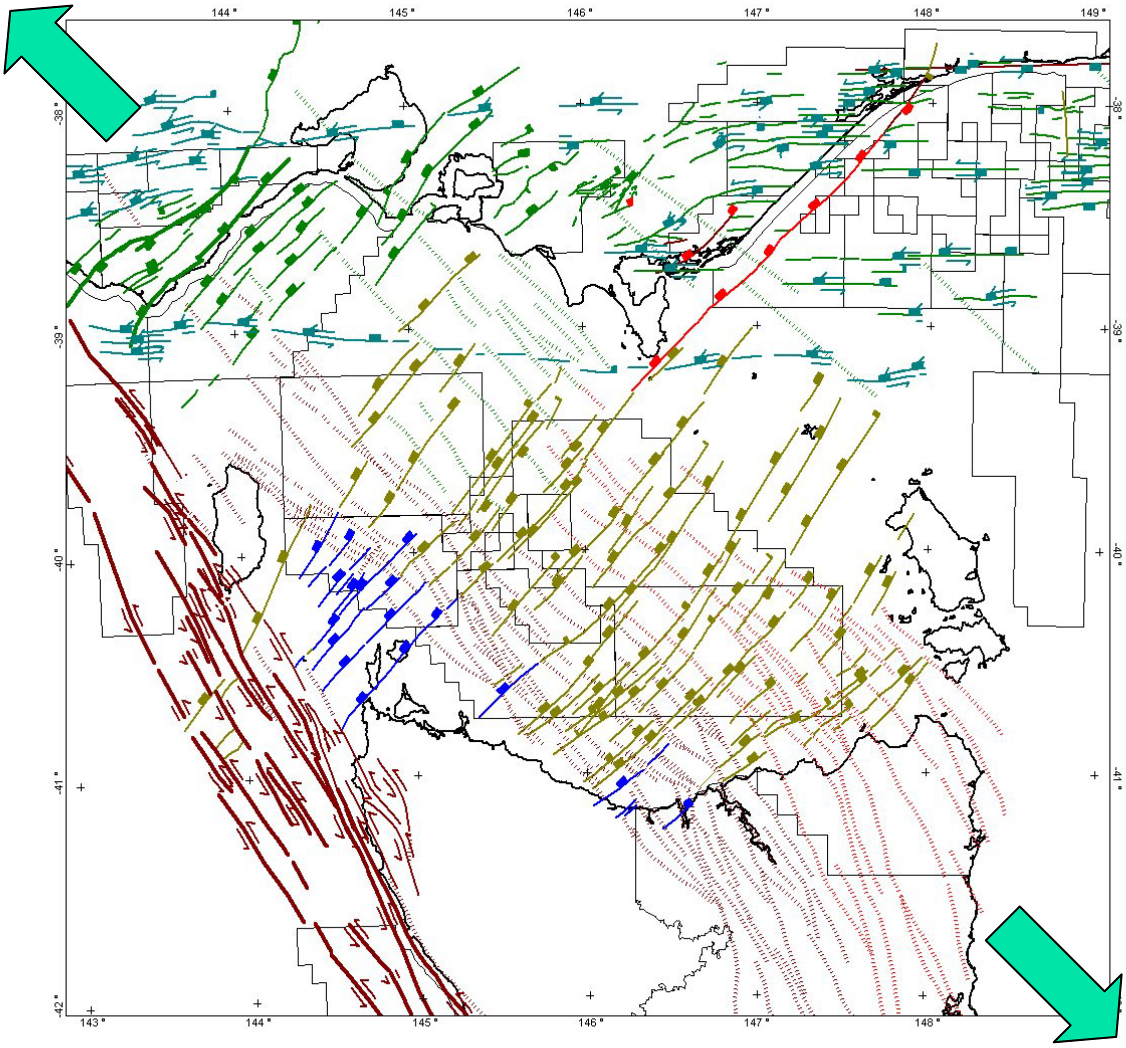
Basin Phase 1: Late Jurassic Extension



The Late Jurassic to Early Cretaceous (~145-120Ma) NW-SE extension marks the last episode of the final break-up of Gondwana. The extension was focussed in western Australia, but was propagated across the southern margin of the continent to the Bass Strait region. A series of linked E-W trending basement faults can be traced from the southern Perth Basin, through the Great Australian Bight and stepping south to the northern margin of the Gippsland and Otway Basins. These structures provided the key "boundary condition" for development of the southern Australian margin basins (eg. Polda Basin and Robe Trough). Extension was probably driven by an attempted separation of Australia and Antarctica while Tasmania is still firmly attached to Antarctica.

These Precambrian E-trending faults underwent oblique left-lateral normal reactivation and generated a set of major NW-trending left-lateral relay zones separating the principal depocentres in the Basins. Major sinistral strike-slip deformation occurred on the SW Ceduna Accommodation Zone, which partitioned significant extension to the west and minor extension to the east forming small, narrow lacustrine basins in the Otway, ?Bass and Gippsland Basins.

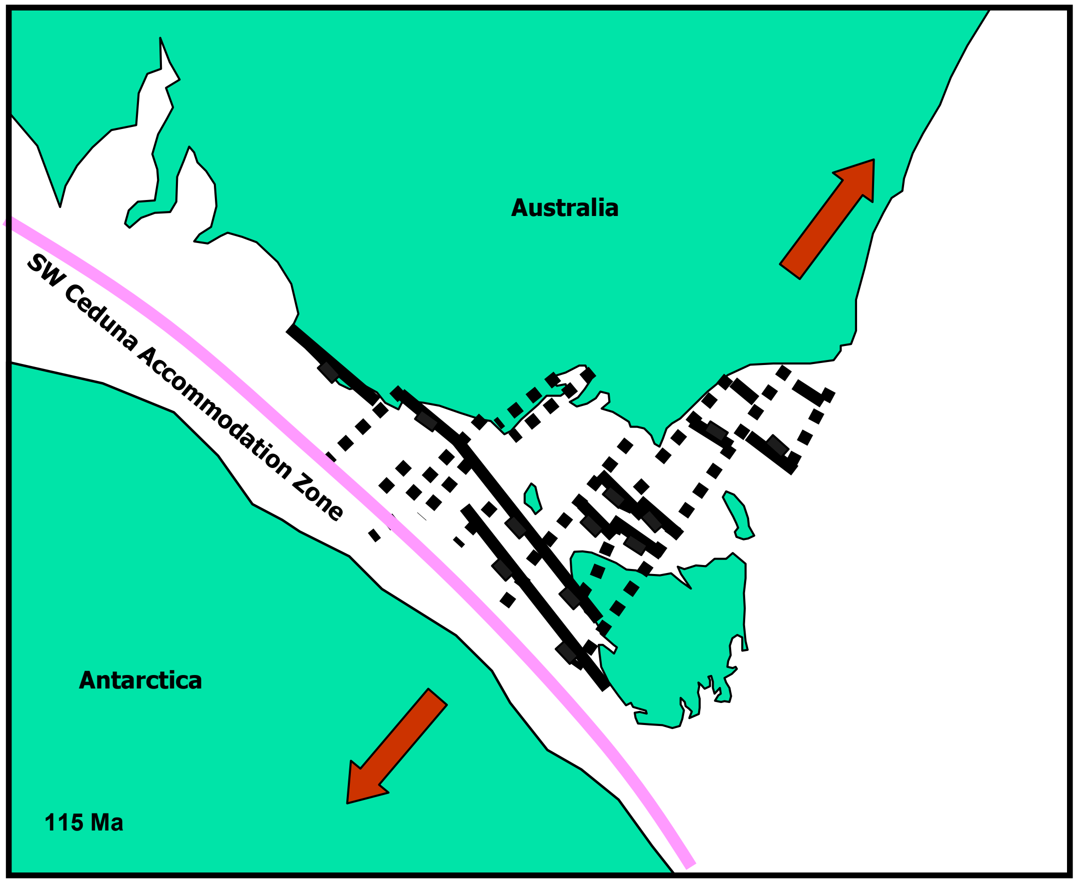
Basin Phase 1: Late Jurassic Extension



In the Bass Strait region, Late Jurassic extension was focussed in the Otway and Gippsland Basins. The extension was NW-directed with normal reactivation of lower crustal Paleozoic NE-trending faults accommodated by oblique left-lateral normal reactivation of E-trending basement faults and generation of major NW-trending left-lateral transfer zones. The latter zones separated the principal depocentres in the Great Australian Bight, Otway, ?Bass and Gippsland Basins.

No Late Jurassic rifting or sedimentation has previously been recognised in the Bass Basin, however the presence of a pre-Cretaceous sequence of unknown age, together with the "availability" of appropriately oriented basement structures possibly indicates that such rifting and sedimentation did occur. The above map is a predictive model for structures that might have been active during Late Jurassic NW-SE extension. It shows minor normal movement on NE trending Early Carboniferous strike slip faults, with Neoproterozoic-Devonian NW structures acting as transfers.

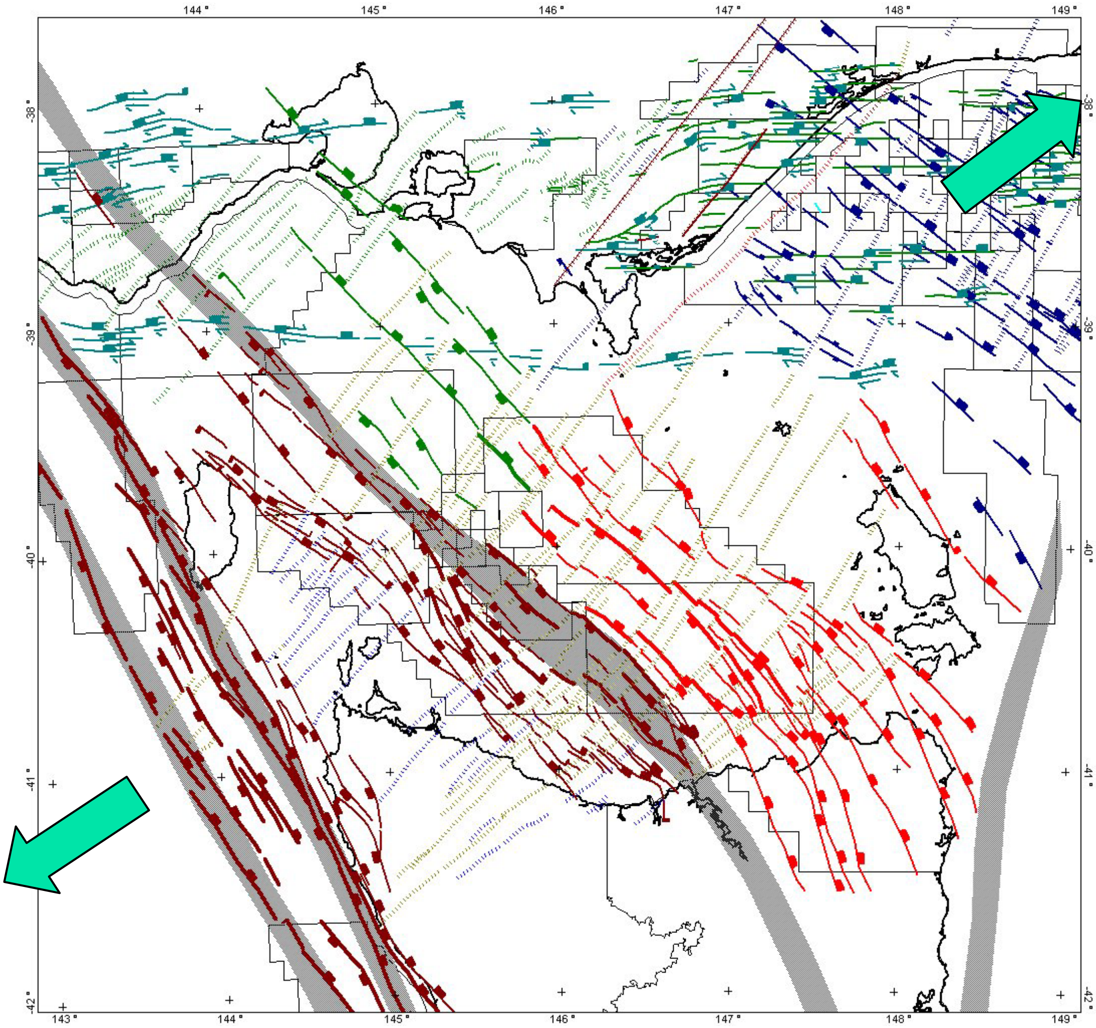
Basin Phase 2: Early Cretaceous Rifting



Early Cretaceous (~120-100Ma) NE-SW extension in Great Australian Bight, Otway, Bass and Gippsland Basins is indicated by the development of major NW-trending growth faults separated by NE-trending transfer zones. Both sets of structures follow older basement structures which evolved during the Neoproterozoic and Paleozoic. Plate tectonic reconstructions (e.g. Muller, 2000) do not show any significant movement between Australia and Antarctica until after 115Ma when Antarctica moves southeastward relative to Australia. It is therefore probable that any NE-extension would most likely to have occurred prior to 115Ma.

The switch in extension direction from NW-directed to NE-directed in the Early Cretaceous resulted in a change of roles for the faults in the basins of SE Australia; the NE structures acting as transfer faults and the NW structures acting as normal faults.

Basin Phase 2: Early Cretaceous Extension

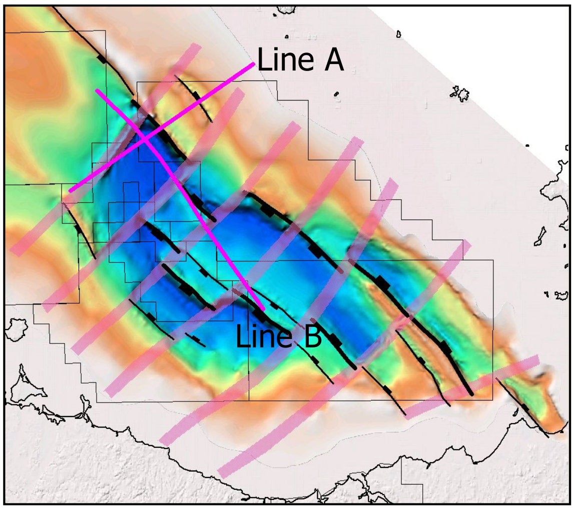


Early Cretaceous (~120-100Ma) NE-SW directed extension established the present-day architecture of the Bass Basin. During this basin phase a thick syn-rift sequence was deposited in deep, NW trending half graben which generally verge to the SW. NW trending normal faults formed by reactivation of major, steeply dipping, Neoproterozoic to Devonian basement structures. Major normal faulting and depocentre development was localized within the Moyston-Tamar Fault Zone. Steeply dipping, NE trending, Early Carboniferous strike slip faults in the basement acted as accommodation zones/transfer faults during this extension, resulting in strong basin compartmentalization. Changes in basement depth of up to 10km and switches in graben vergence are observed across these accommodation zones.

Only minor Early Cretaceous extension is interpreted to have occurred in the Durroon Sub-basin at this time.

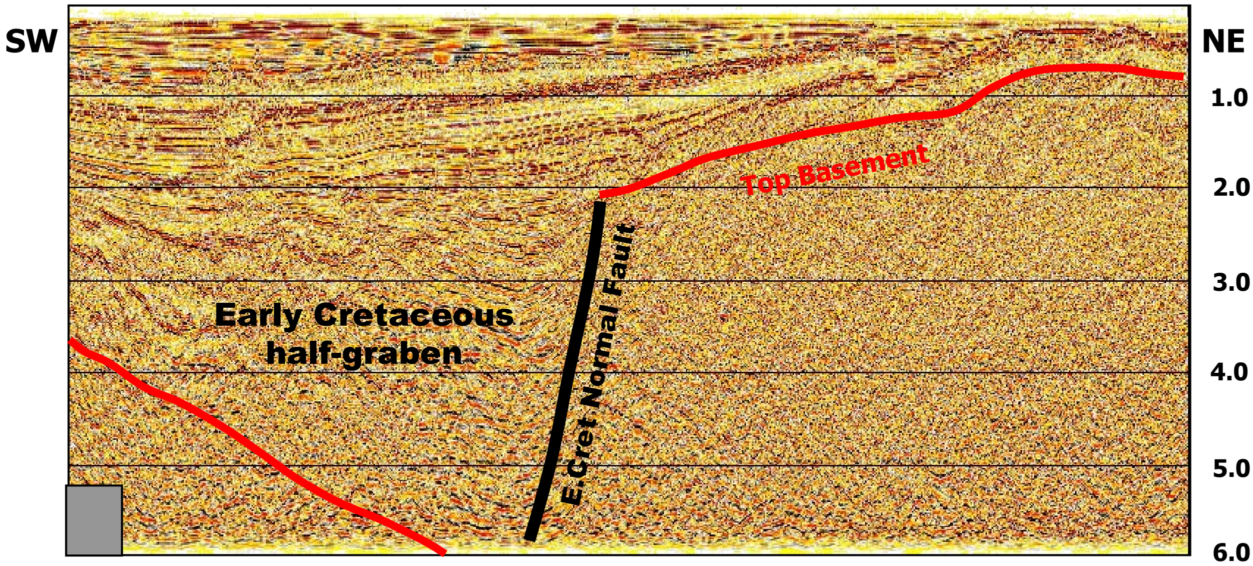
Seismic examples of Early Cretaceous extensional structures are shown overleaf.

Basin Phase 2: Early Cretaceous Extension

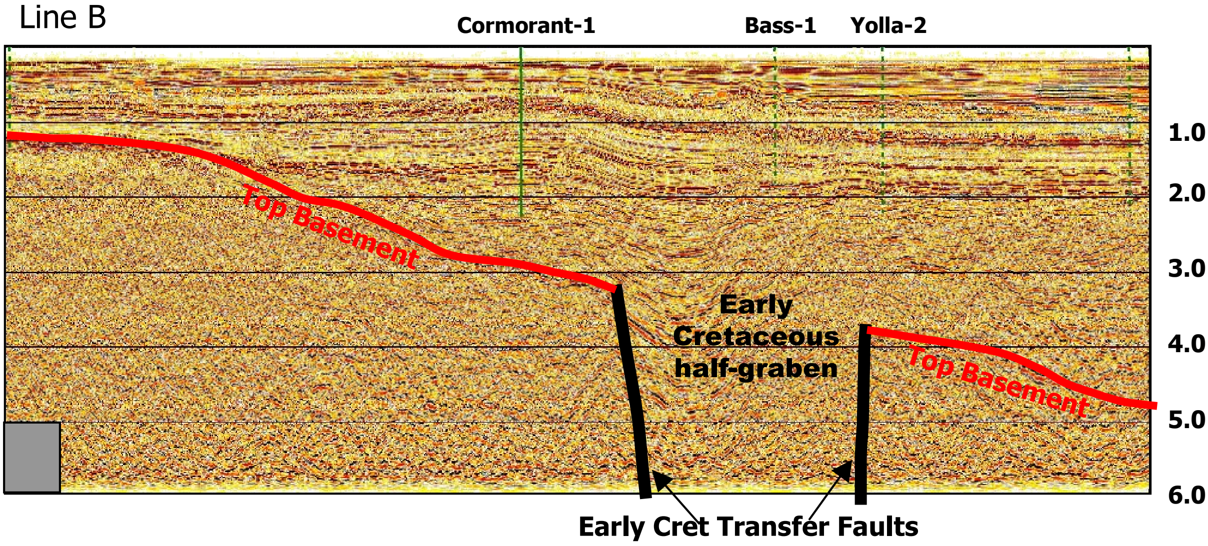


Seismic example of Early Cretaceous half graben/basin compartment. Line A provides a cross section perpendicular to a major SW dipping normal fault. Line B provides a cross section parallel to this normal fault in the deep part of the half graben showing the accommodation structures bounding this basin compartment.

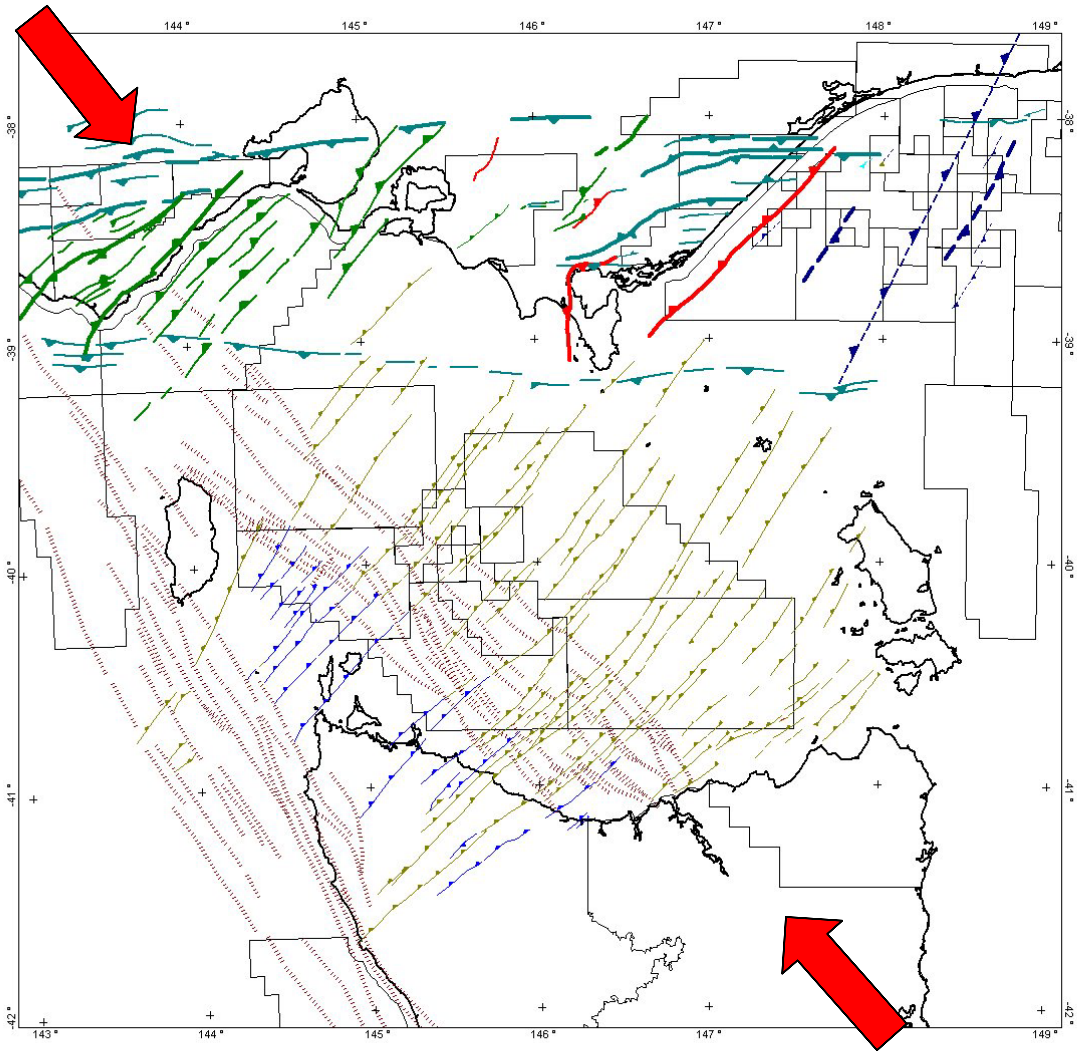
Line A



Line B



Basin Phase 3: Mid-Cretaceous Inversion

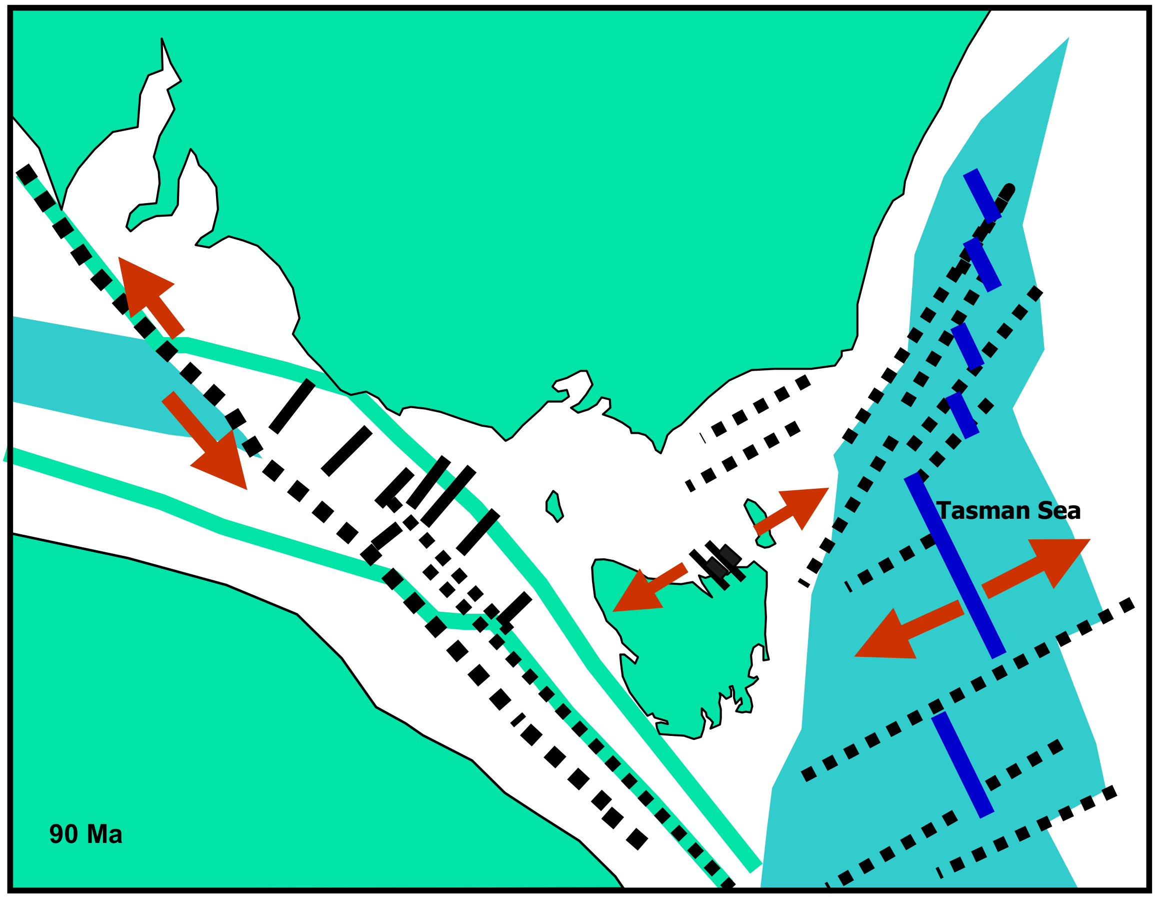


Mid-Cretaceous (~100-90Ma) compression caused extensive uplift of the Strzelecki and Otway Ranges, and inversion in the Gippsland Basin. The cores of the resulting major anticlines have an associated positive gravity anomaly. Inversion of both Jurassic growth faults and Cretaceous accommodation structures reflects a NW principal stress direction.

No Mid-Cretaceous inversion structures have previously been recognised in the Bass Basin, however we tentatively attribute the ìbumpsî observed in NW trending seismic lines to have formed during this event. If such structures are in fact Mid-Cretaceous then this inversion event was probably quite widespread in the Bass. The above map shows which structures are likely to have been inverted during the Mid-Cretaceous. NE trending Early Carboniferous faults are likely to have been reactivated as reverse faults, separated by NW trending accommodation zones.

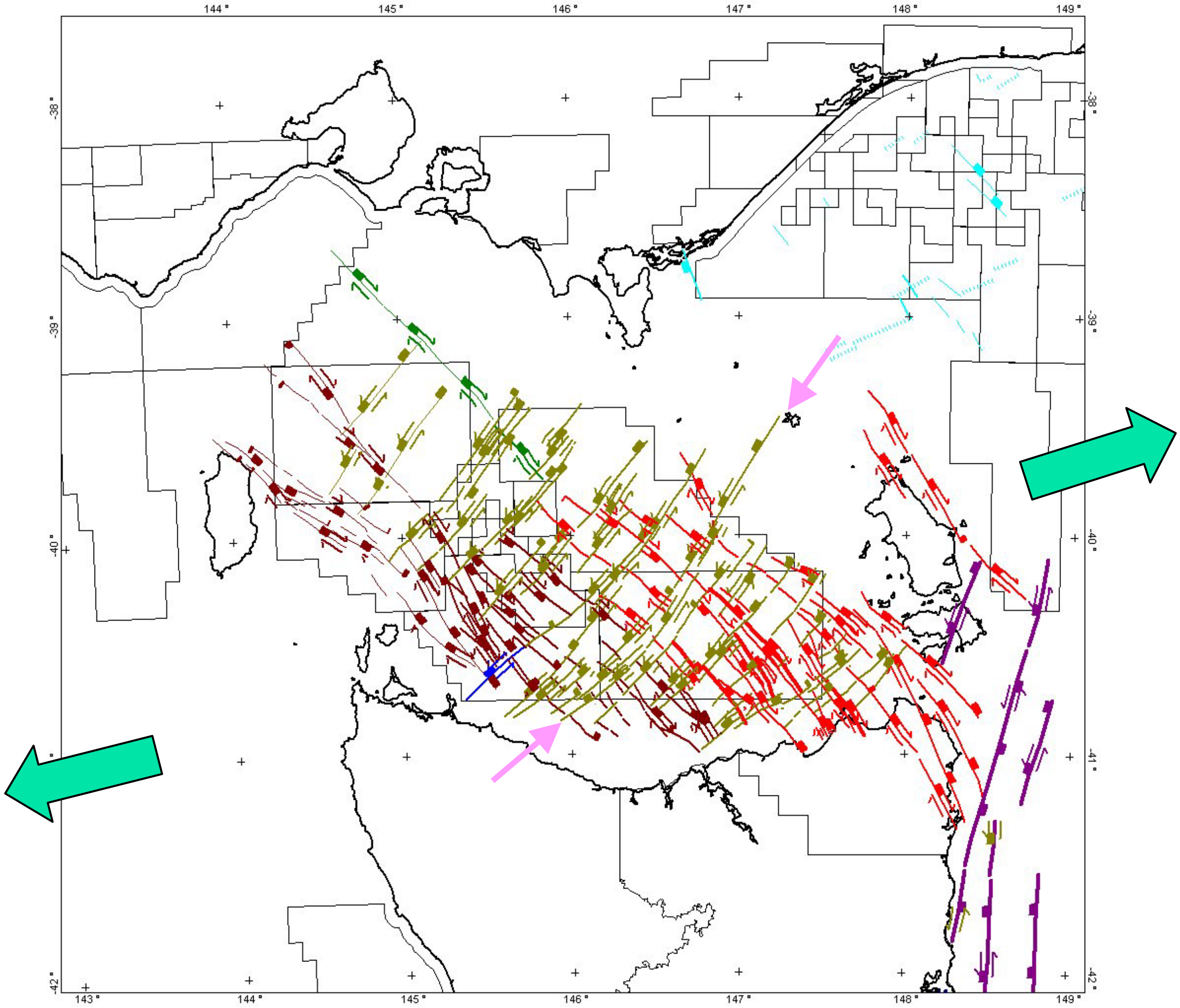
Extensive uplift occurred in northern Tasmania and Bass Strait at this time (as evidenced by Fission Track data ñ Dumitru et al, 1991; OíSullivan, 1994). The sharp ìhingesî observed at the edge of the early Cretaceous half graben probably originated at this time due to erosion of the hangingwall ìbulgeî.

Basin Phase 4: Late Cretaceous Extension



ENE directed rifting in the Late Cretaceous (~90-80Ma) terminated with break-up and seafloor-spreading in the Tasman Sea. The oldest age of Tasman oceanic crust interpreted is ~80Ma (GA timescale) or 83Ma (Mulleris reconstructions). Extensive Late Cretaceous volcanism at the main rift margins (ie. to the east of the Bass Basin) was associated with the latest stages of extension and the onset of sea floor spreading. Non-marine clastic deposition in the Bass and Gippsland basins between 90Ma and 80Ma marks the initiation of Late Cretaceous extension.

Basin Phase 4: Late Cretaceous Extension

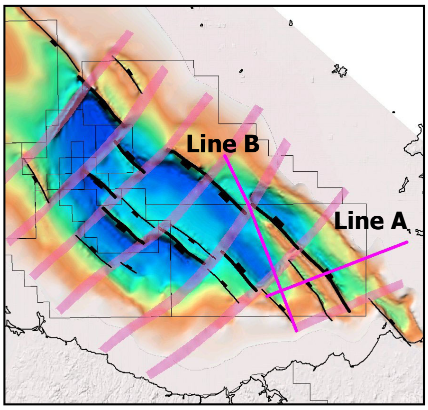


In the Bass Basin, ENE directed Late Cretaceous extension reactivated the same pre-existing NE and NW basement fabric exploited during the Late Jurassic and Early Cretaceous basin phases. Since the Late Cretaceous extension direction was oblique to this pre-existing NE-NW orthogonal basement fabric, minor rotation/tilting of the basement blocks occurred in the main part of the Bass Basin.

Major extension in the Durroon Sub-basin occurred at this time, mainly on NE dipping, NW trending normal faults. Again the NE trending Early Carboniferous faults acted as accommodation zones, and also underwent a minor component of dextral strike slip movement.

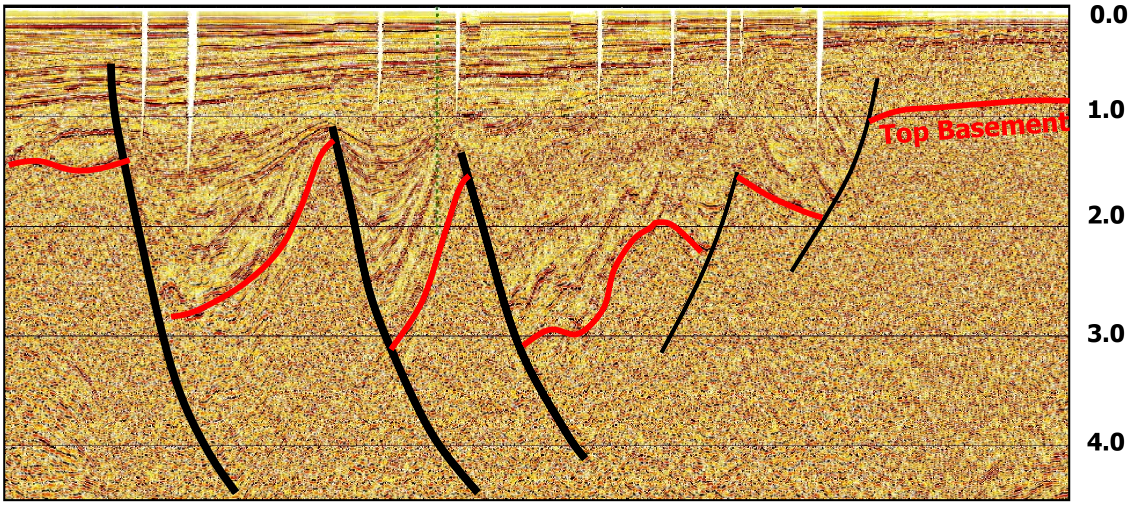
Major extension in the Durroon Sub-basin was separated from minor extension in the main part of the Bass Basin by a NE trending accommodation zone shown above by the narrow pink arrows.

Basin Phase 4: Late Cretaceous Extension

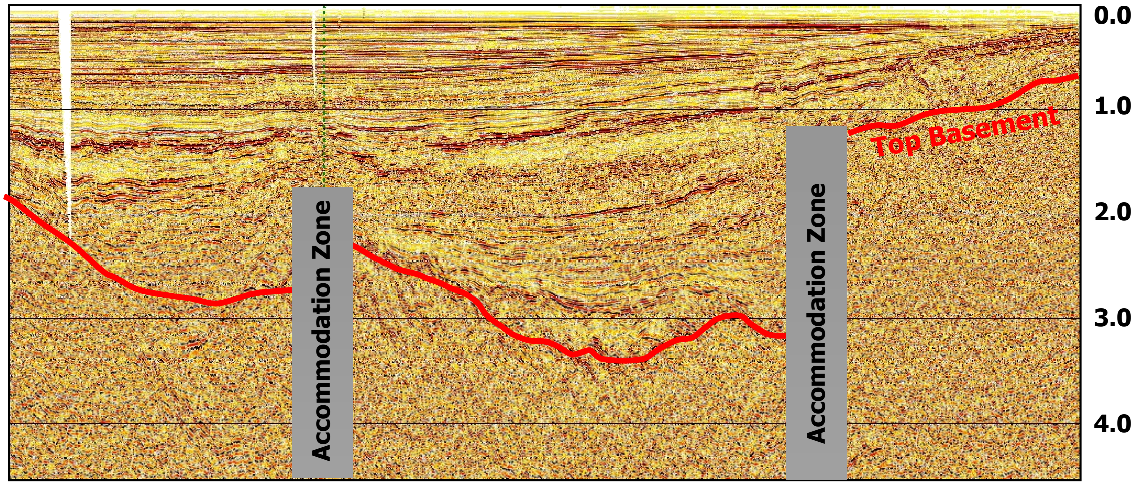


Seismic examples of Late Cretaceous half graben/basin compartments in the Durroon Sub-basin. Line A provides a cross section perpendicular to the NW dipping normal faults. Line B provides a cross section parallel to the normal fault showing the accommodation zones bounding this basin compartments.

Line A



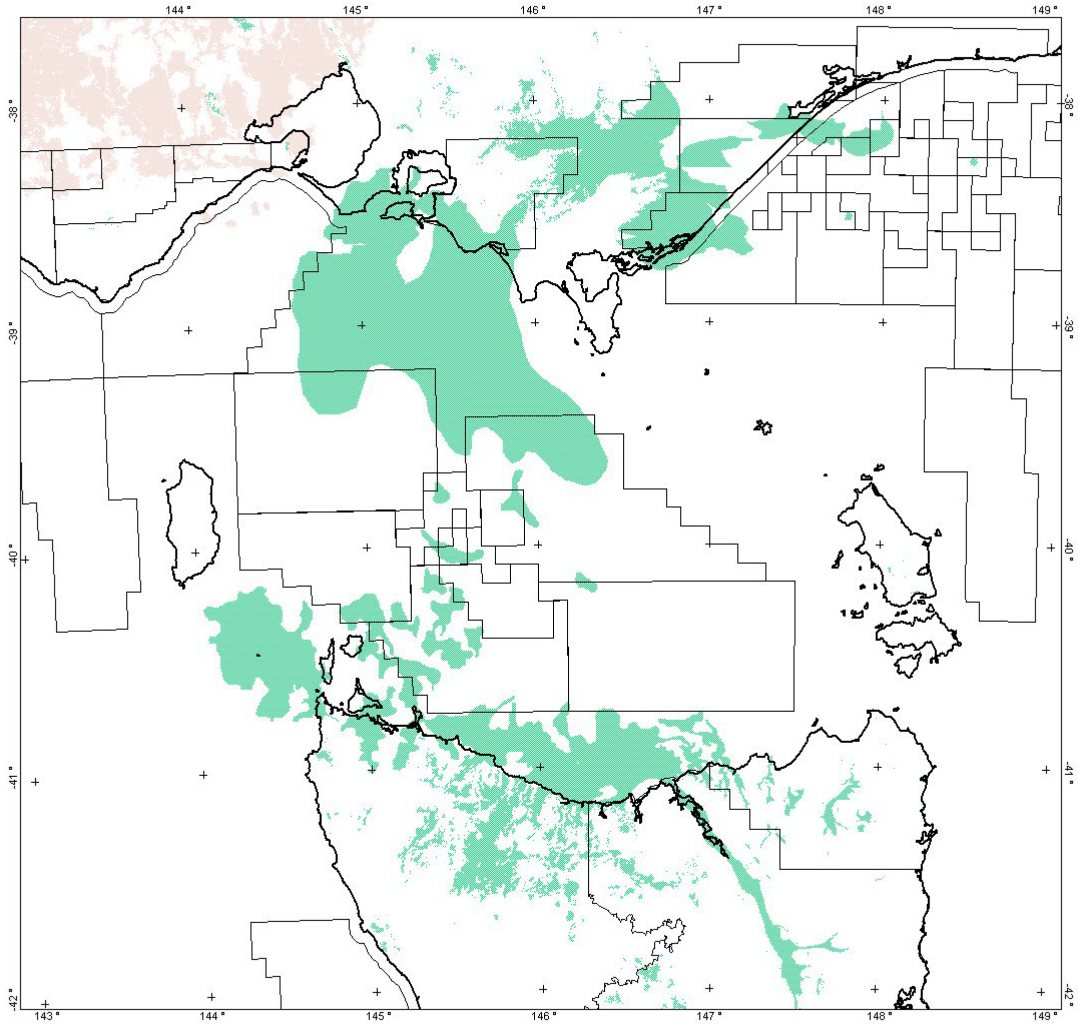
Line B



Basin Phases 5, 6 & 7: Tertiary Sag

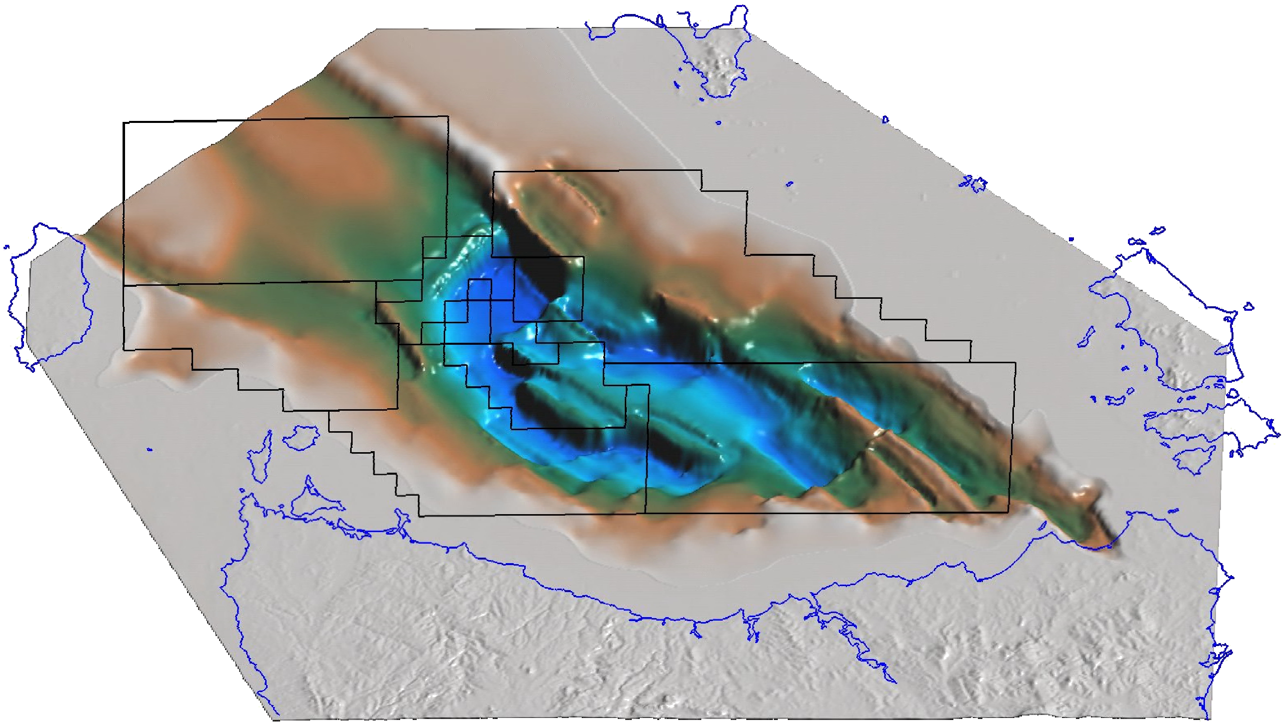
Up to 2km of sag phase sediments have been deposited in the Bass Basin during the Tertiary. In the seismic data these sediments are virtually unstructured, and have clearly not been effected by the Eocene inversion event observed in the Otway and Gippsland Basins (Basin Phase 6). Very minor normal faulting at the basin margins has occurred during the late Tertiary (?Miocene).

Tertiary – Recent Volcanism



Volcanic activity in SE Australia has been fairly continuous throughout the Tertiary to Recent, with peaks in the Paleocene-Eocene (~55Ma, shown above in green) and Plio-Pleistocene (shown above in pink). This volcanism has been cause by the Australian plate moving over mantle hotspots, and continues today in the Mt Gambier region of South Australia. The offshore extent of Tertiary volcanics in Bass Strait is relatively poorly constrained due to the poor quality aeromagnetic data on which the interpretation relies.

Depth to Basement



SEEBASE™ (Structurally Enhanced View of Economic Basement)

What is SEEBASE™?

SEEBASE™ is much more than just another magnetic depth-to-basement model. It is the culmination of a number of calibration and integration steps:

- Integrated structural/kinematic interpretation
- Geophysical modeling
- Seismic & well calibration
- Integration of tectonic events & responses

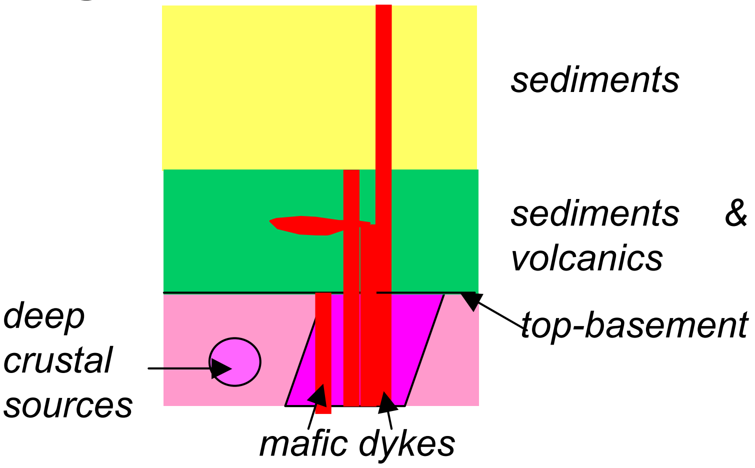
SEEBASE™ is a qualitative model of economic basement topography that is consistent with the structural evolution of the basin. SEEBASE™ defines basin architecture, and is a predictive model for exploration. It is a key base for understanding basin phase geometry/distribution and petroleum systems. As new data are acquired that allows more precise calibration, SEEBASE™ can be updated to reflect all new information.

SEEBASE™ provides a foundation for petroleum systems evaluation, including play element distribution (source/reservoir/seal), migration pathways, zones of structural complexity, trap distribution, trap type & integrity, paleogeography, oil vs. gas distribution etc.

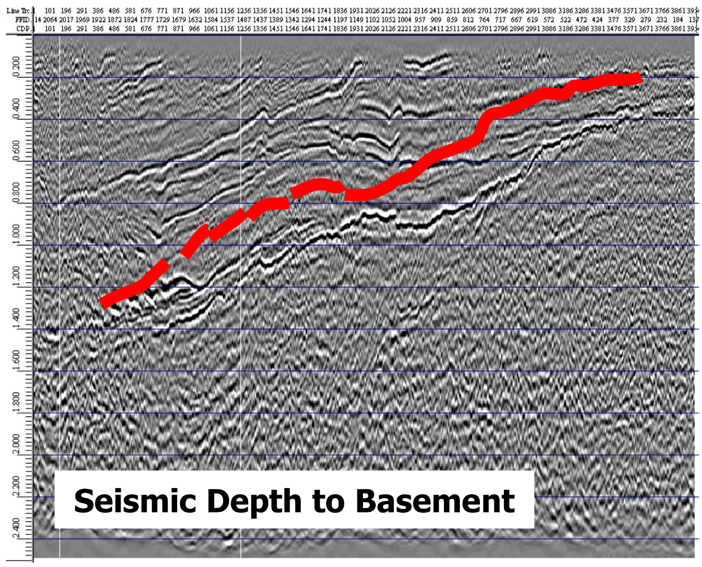
SEEBASE™ Methodology

1. Depth models to magnetic basement sources, obtained from profiles across selected anomalies
2. Attribution of source type to depth estimates (require top-basement sources)
3. Identification of major basement-involved faults
4. Integration of event/response history
5. Integration of gravity modeling & interp (if available)
6. Incorporation of refraction/seismic/well data (if available)
7. Intelligent contouring of "top basement" depth estimates
8. Grid construction using CPS-3
9. 2D and 3D image processing in ERMapper

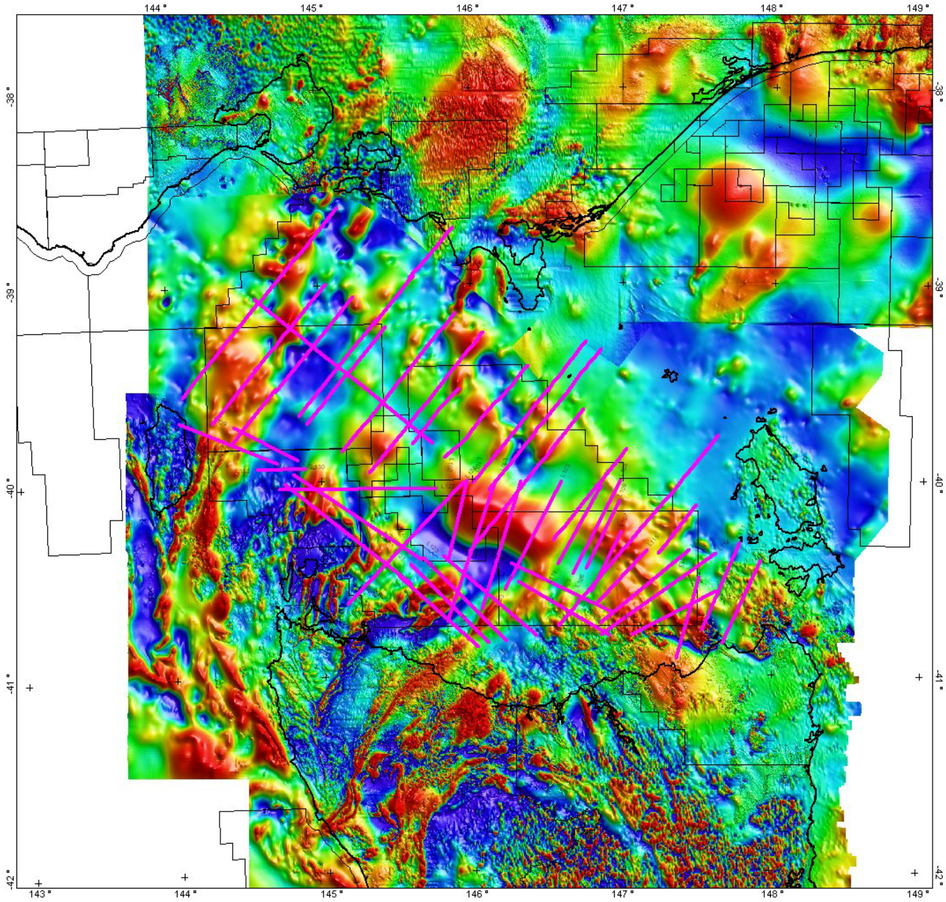
Magnetic Sources



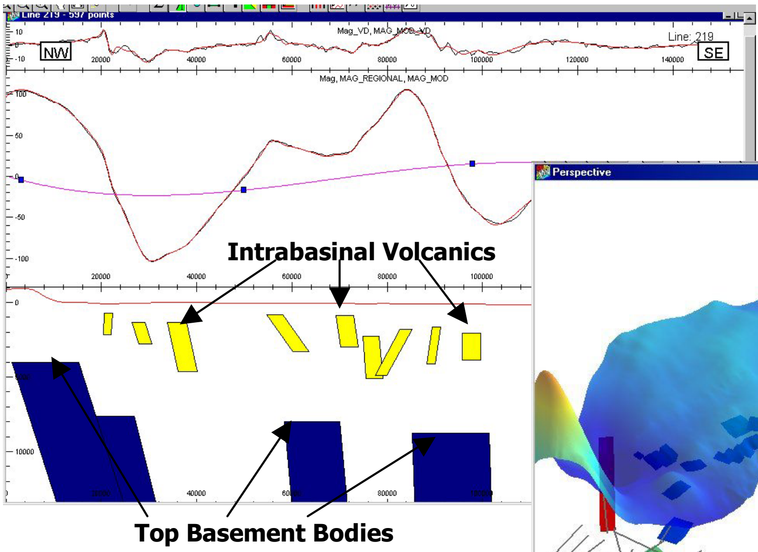
Calibration Example



Magnetic Profiles

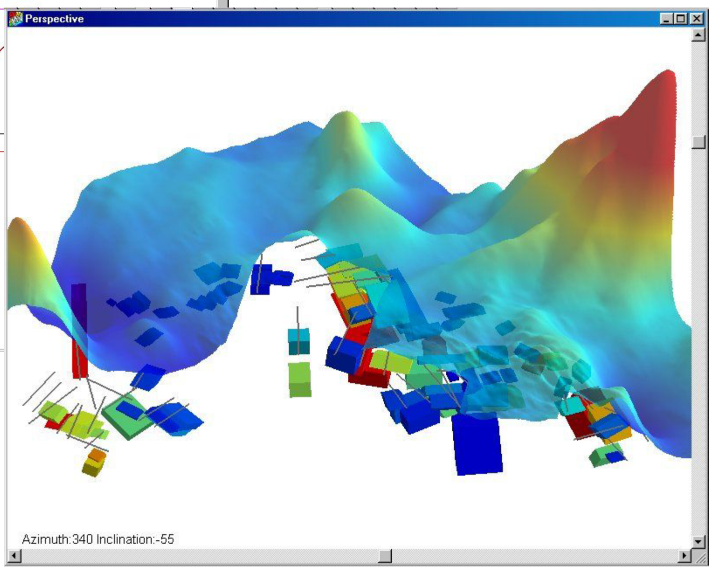


Modeled Profiles & Modeled Bodies

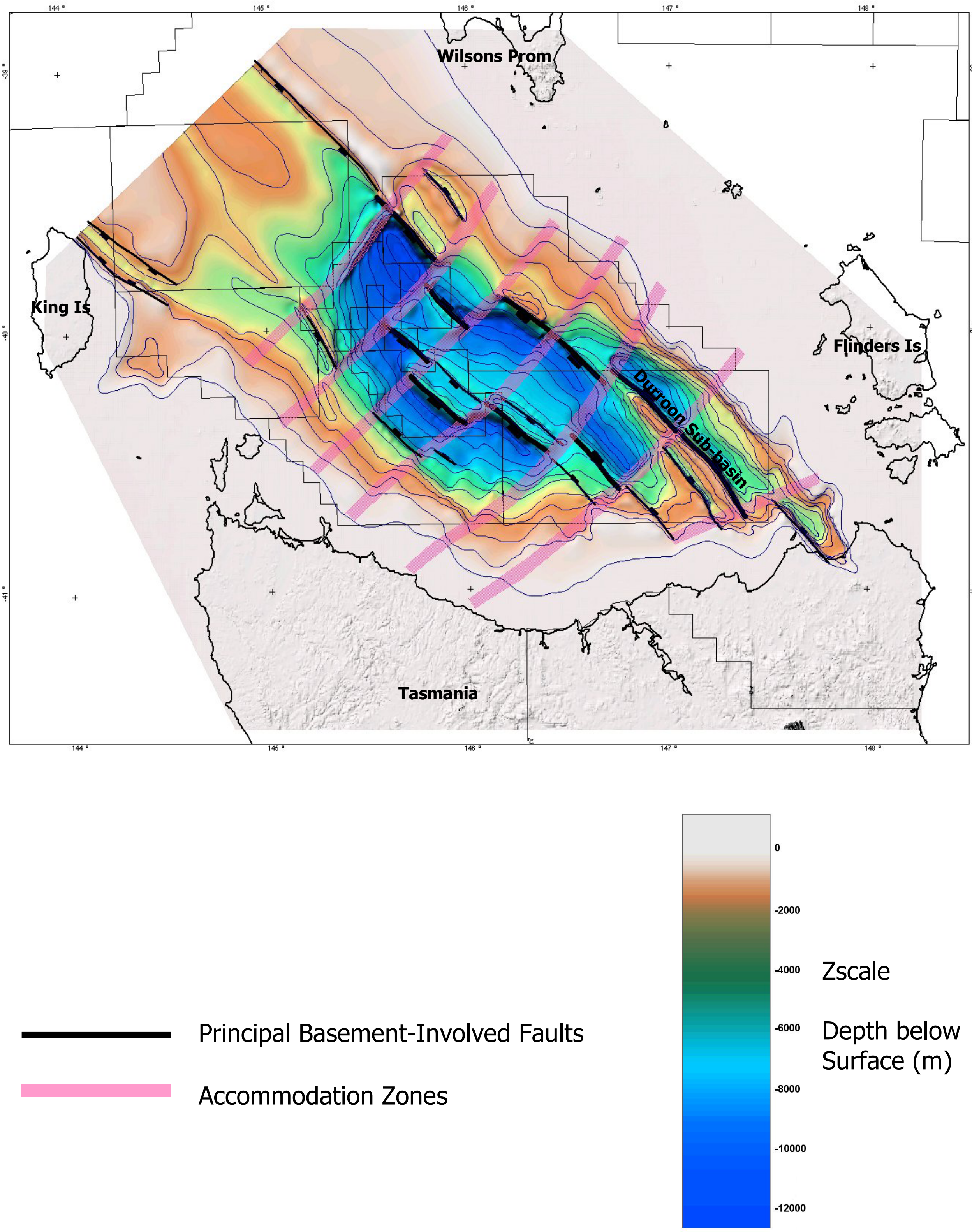


ModelVision™ outputs

encom



Bass Basin SEEBASE™



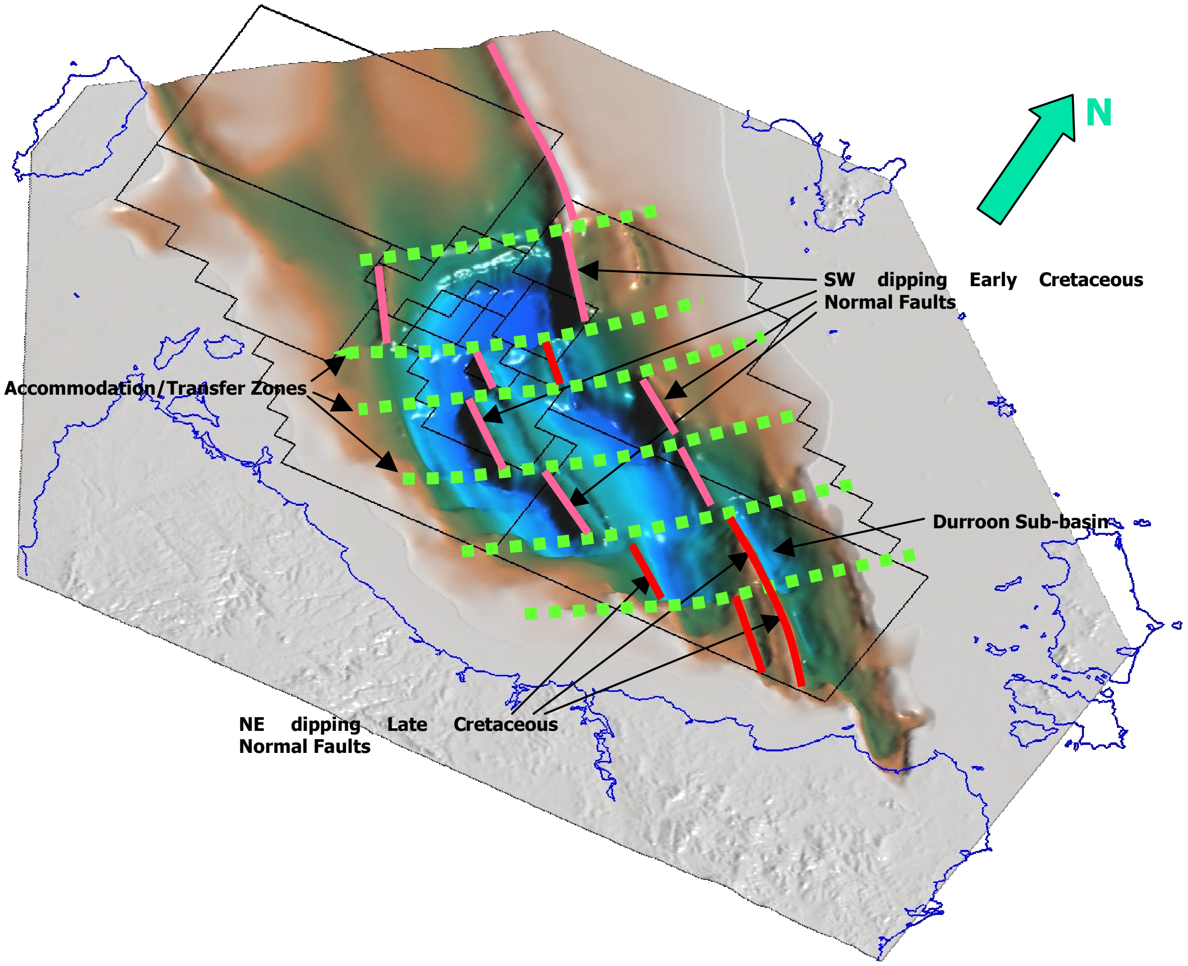
Bass Basin SEEBASE™

Magnetic depth to basement modeling was very successful in the southern parts of the Bass Basin due to dyke-like source geometries of linear Cambrian volcanics, and good data quality. As a result, this SEEBASE™ dataset is probably accurate to ±10% in areas where magnetic data quality is good. In the northern parts of the Bass Basin, magnetic modelling relied on poor quality, old magnetic data, and even though raw profile data was used for modelling, only the deeper parts of the basin were accurately modelled.

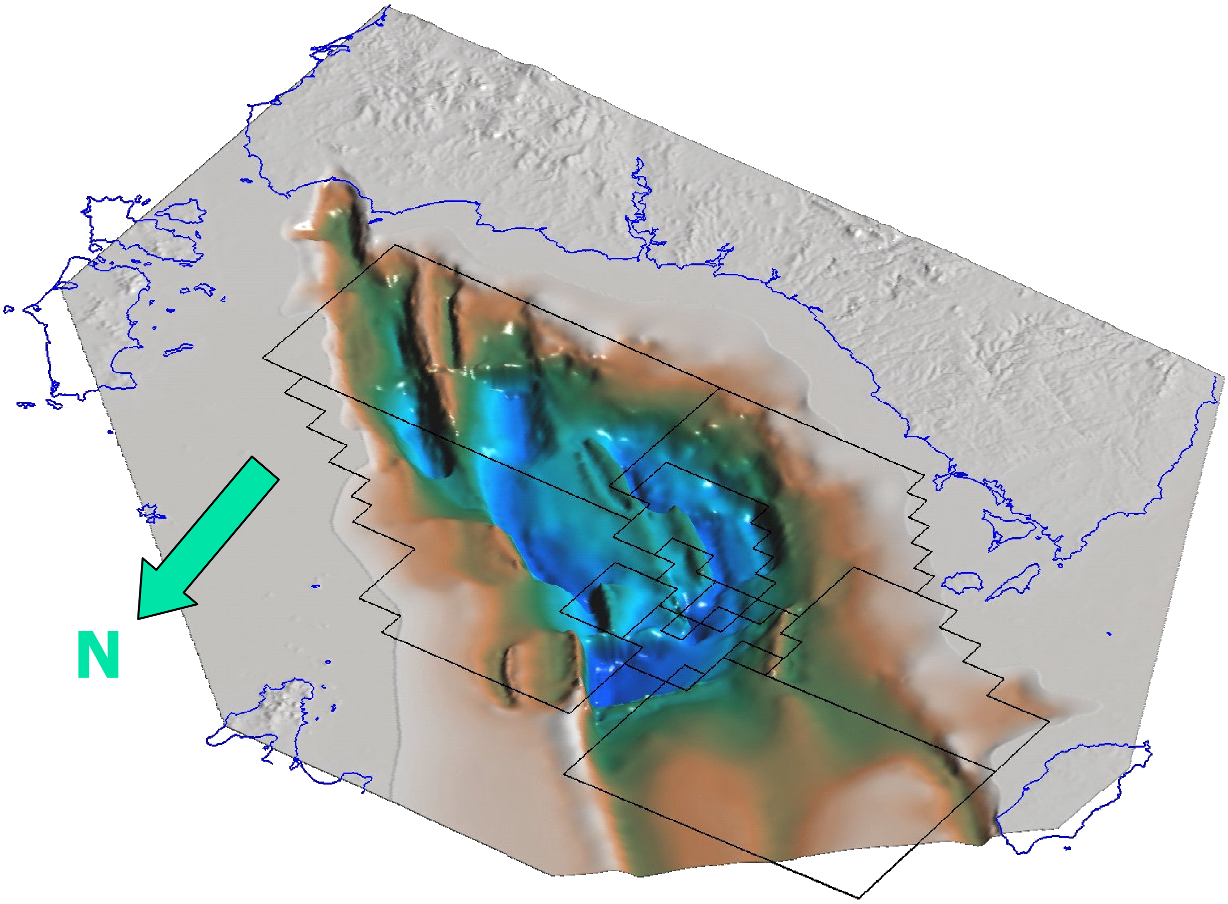
SEEBASE™ images of the Bass Basin show basin architecture, and can be used to analyse petroleum systems and basin phases. Despite the complex basement fabric and multi-phase basin evolution, the architecture of the Bass is quite simple.

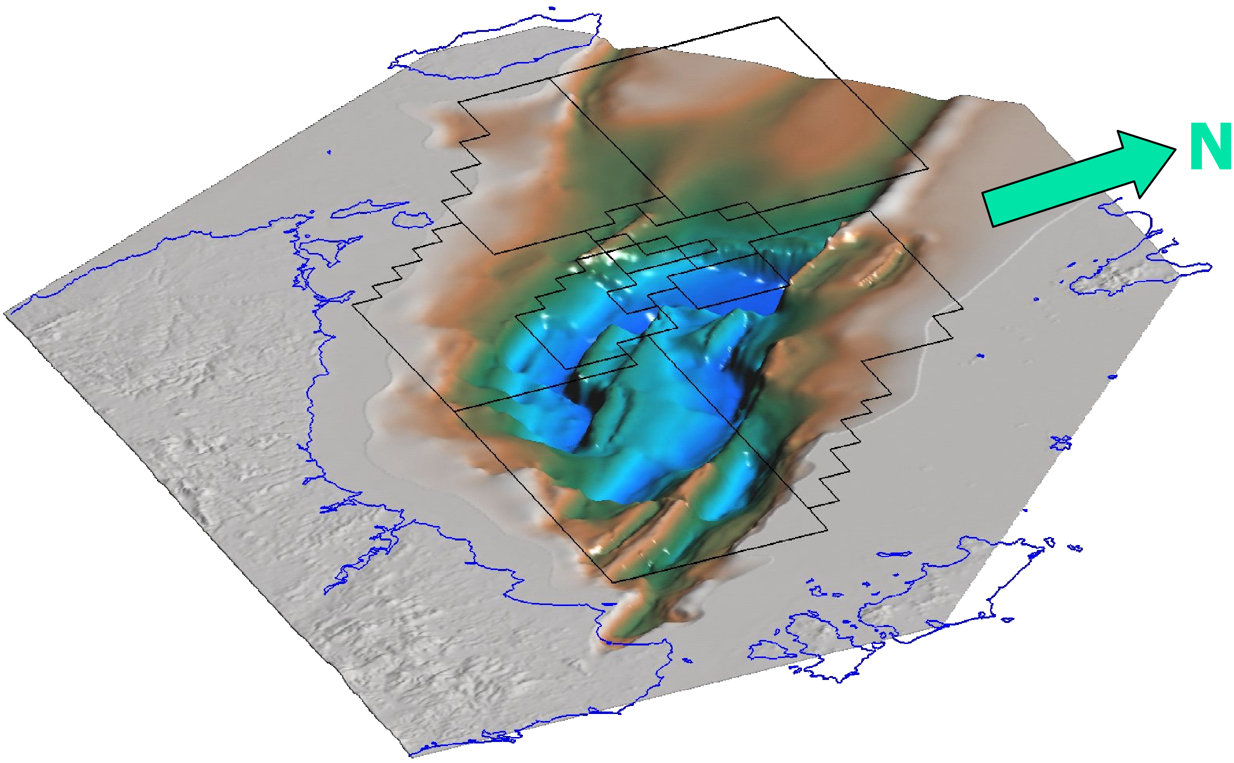
Significant features evident in the Bass Basin SEEBASE™ include:

- Bass Basin architecture dominated by NW trending half graben.
- Basin compartments defined by NW trending Early and Late Cretaceous normal faults and NE trending accommodation zones.
- Changing polarity of half graben across major accommodation zones.
- Abrupt NW margin of Bass Basin defined by major accommodation zone/sidewall fault.



3D Views of Basin Architecture





Basement Controls on Basin Architecture

The Bass Basin SEEBASE™ study has shown that basement geology (particularly structure) is a first order control on basin architecture. Reactivation of basement structures can be used to explain the structural evolution of the Bass during the Mesozoic. The key findings of this study are as follows:

- The basement geology of the Bass Basin is dominated by two key Neoproterozoic to Paleozoic basement terranes; the Kanmantoo and Lachlan Fold Belts.
- The boundary between the 2 basement terranes is the Moyston-Tamar Fault Zone; a major NW trending array of structures which later became the locus of Mesozoic extension.
- The present-day geometry of the Bass Basin was established during early Cretaceous NE-SW extension.
- Basin architecture is largely controlled by basement structures, composition, fabric and rheology.
- NW trending basement shear zones/terrane boundaries were a first-order control on basin evolution during the Mesozoic.
- NE trending early Carboniferous faults were a second-order control on basin evolution during the Mesozoic.
- The geometry of the Bass Basin is defined by deep half-graben compartmentalized by major accommodation zones and/or transfer faults.
- Seven basin phases/tectonic events have shaped the Bass during the Mesozoic and Tertiary.
- A SEEBASE™ model for the Bass Basin shows basement topography, and can be used to map basin phase distribution, migration pathways and trap type/distribution.

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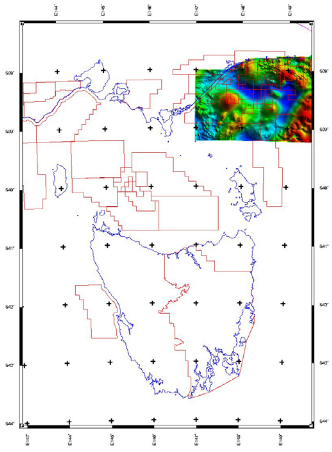
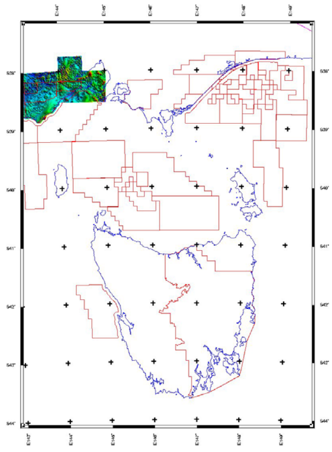
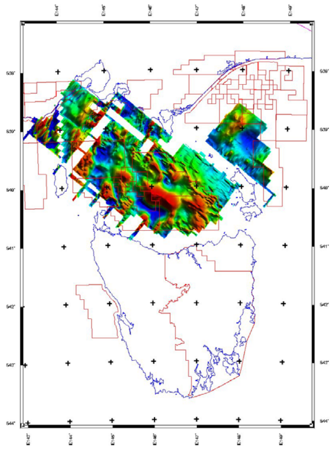
Appendix 1: Magnetic Datasets



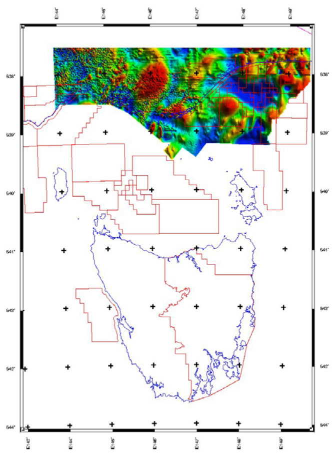
AGSO 1999 400m Gippsland Survey



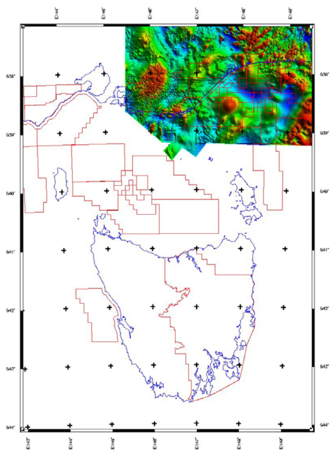
VIMP 1999 200m Colac Survey



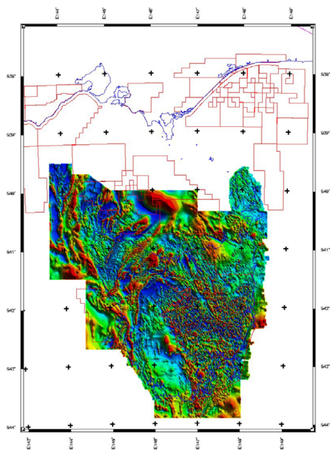
Bass Strait 1961 3.2km Survey



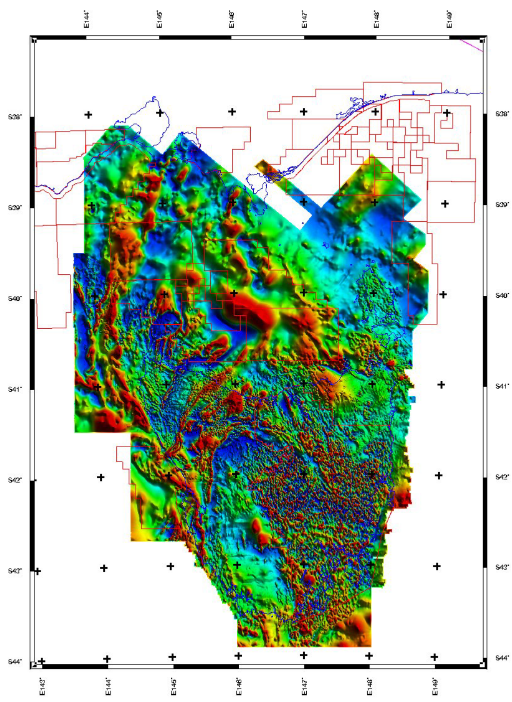
AGSO 400m Melbourne-Bodalla grid



VGS 2000 SE Victoria 100m grid



AGSO 2000 100m Tasmania grid



2001 SRK/Encom stitch of reprocessed Bass Strait 1961 data and AGSO 2000 magnetic grid of Tasmania (done for this project).