

# Bass Basin T39/P Permit Structural Model & SEEBASE™ Study

## REPORT

October, 2005

Proj Code: BAN701



BENARIS PETROLEUM N.V.

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## Executive Summary

• In May 2005, Benaris contracted FrOG Tech to develop a revised, more detailed SEEBASE™\* model for the Bass Basin T39/P permit. FrOG Tech has **extensive basin analysis experience** in southern Australia, including the Bass Basin.

• FrOG Tech's approach utilizing non-seismic and seismic datasets facilitates regional geological evaluations that go far beyond those possible using seismic data alone, especially so in basins with limited or poor quality seismic coverage.

• The aim of this study is to generate a SEEBASE™ model for Benaris' Bass Basin T39/P permit, that defines:

- Basement depth and basin shape
- Location and architecture of sub-basins / troughs
- Location, geometry and reactivation history of major structures
- Deep structural controls on Tertiary trap fairways and prospects
- Possible "new" trap fairways

• This study builds upon FrOG Tech's 2001 Bass Basin SEEBASE™ Project which provided an integrated regional interpretation of basement composition, structure and depth in the Bass Basin. The main difference between this study and the 2001 study is the interpretation of an interpretation of Benaris' 2D seismic data.

• The Bass Basin T39/P SEEBASE™ study presents a refined view of the structural evolution and architecture of the southern Bass Basin. The results give Benaris a top-basement pick that is consistent with existing seismic and non-seismic data and a new base with which to understand the deep structure and basin geometry of T39/P.

Key technical outcomes of the study include:

### Datasets and Calibration:

• Datasets compiled and processed for the Bass Basin SEEBASE™ Project (Teasdale et al, 2001) were used in this study, which builds upon the previous interpretation.

• The main additional data used for this study was the reprocessed 2D seismic database purchased by Benaris from Fugro.

### Basement Geology:

• The basement terranes, composition and structure of the Bass Strait area have been interpreted. T39/P spans two basement terranes which underwent complex Neoproterozoic-Paleozoic evolution.

• The location and geometry of basement structures was interpreted, with a view to understanding how pre-existing basement structures have influenced later basin evolution.

### Basin Structure and Evolution

- Three key structural events are important in the Bass Basin:
  - (i) Early Cretaceous NE-SW rifting
  - (ii) Late Cretaceous "Tasman Sea" ENE-WSW rifting
  - (iii) Subtle Mid-Late Miocene inversion

• Two sets of major basement structures have significantly influenced Mesozoic-Cenozoic basin evolution:

(i) NW-trending Paleozoic structures/terrane boundary have localized Cretaceous rifting and were reactivated as normal and oblique normal faults. These structures bound the main depocentres in the Bass Basin

(ii) NE-trending Neoproterozoic structures have been reactivated as transfer/accommodation zones during both Cretaceous rift events. These structures compartmentalize the rift structures in the Bass Basin.

• In this study we have undertaken a detailed interpretation of the location and geometry of these rift structures in T39/P.

### Basement Architecture and Depth - SEEBASE™

• A SEEBASE™\* model of T39/P defines basement topography and basin architecture. SEEBASE™ was constructed using a combination of seismic top-basement interpretation, magnetic depth modeling, and structural interpretation. SEEBASE™ can also be used to map play element distribution, migration pathways and trap type/distribution.

• The T39/P SEEBASE™ and structural interpretation clearly shows the tilted fault block geometry of the south-central Bass Basin, including the Pelican and Bark Troughs. The Chat Accommodation zone forms a major NE-trending structural corridor which compartmentalizes the basin.

### Implications for Prospectivity

• Mid-Late Miocene inversion of deep Cretaceous normal faults is responsible for closures at Eastern View level.

• Benaris' main "PJ" prospect formed via Miocene inversion of an Early Cretaceous normal fault.

• The "PJ" prospect lies within the Chat Accommodation Zone, which is probably responsible for the along-strike closure of "PJ". Hence "PJ" prospect appears to occur in a structural "sweet spot" at the intersection of two major structural corridors.

• Other prospects such as Pelican also formed during Miocene inversion of deep Cretaceous normal faults, however the absence of NE-trending "cross" structures may have prevented the development of along-strike closures at Eastern View reservoir level.

• Further similar "sweet spot" prospects may occur near the intersections of NW-trending inverted normal faults and NE-trending accommodation zones.

• Top-basement relay ramps near "PJ" may have acted as migration pathways from any deeply-sourced hydrocarbons in the Pelican Trough into "PJ".

### GIS:

• All interpretive layers are captured digitally in ArcGIS format.

\*SEEBASE™ = Structurally Enhanced view of Economic Basement



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## Recommendations

- Use the structural interpretations and SEEBASE™ grid presented here to guide seismic interpretation and prospect generation.
  - Load SEEBASE™ grid + structures into seismic workstation
  - Use SEEBASE™ to help locate top-basement pick
  - Use structural interpretation to help locate fault blocks and inversion features
  - Use SEEBASE™ + structural interpretation to identify possible new structural “sweet spots”
- Use the structural interpretations + SEEBASE™ to guide future seismic acquisition programs.
- Update this study if new seismic data is acquired.
- Extend this study to cover other parts of the Bass Basin.
- Reprocess T39/P magnetic data to reduce noise levels and facilitate further enhancement processing + modeling. This would enable an incremental improvement in the interpretations presented here.



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## Introduction & Background

- Benaris holds several petroleum exploration permits in SE Australia, including the Bass Basin Permit T39/P.
- T39/P has had no wells drilled in it to date. It covers a relatively poorly understood portion of the south-central Bass Basin, at the eastern end of the Pelican Trough.
- Benaris has interpreted existing 2D seismic down to an intra-Eastern View Group pick (~Late Paleocene). One significant prospect has been identified (“PJ” prospect), and several regional structural trends have been identified. Follow-up seismic surveys are being planned.
- Current 2D seismic data in T39/P is of variable quality and coverage, and is generally insufficient for mapping and understanding deep basin structure and architecture. Such an understanding is necessary to explain known prospects and predict the location and nature of undiscovered structural fairways.
- In 2001, FrOG Tech (then SRK Consulting Energy Services) completed the Bass Basin SEEBASE™\* Project (Teasdale et al, 2001), which provided an integrated regional interpretation of basement composition, structure and depth in the Bass Basin. The interpretation was based largely on gravity and magnetic data, with very limited seismic and well calibration. The results are regional in scale and cover the entire Bass Basin and surrounding areas. The 2001 study was used as a base for this study.
- In May 2005, Benaris contracted FrOG Tech to develop a revised, more detailed SEEBASE™ product for T39/P. Since no new potential field data is available for the area, seismic data provides the most effective tool for enhancing the 2001 SEEBASE™ model.

## Aims

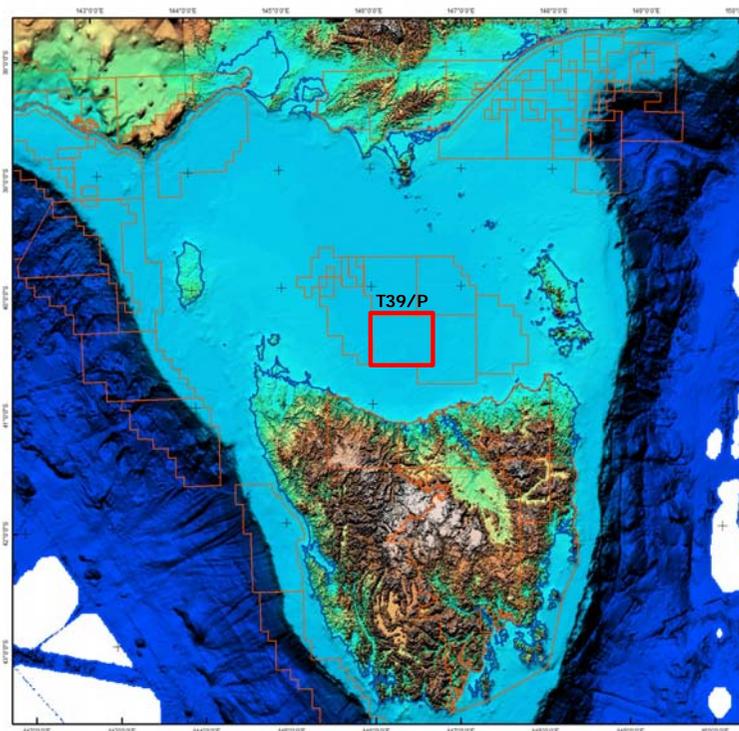
- The aim of this study is to generate a SEEBASE™ model for Benaris’ T39/P permit, that defines:
  - Basement depth and basin shape
  - Location and architecture of sub-basins / troughs
  - Location, geometry and reactivation history of major structures
  - Deep structural controls on Tertiary trap fairways and prospects
  - Possible “new” trap fairways
- The results provide Benaris with a new base on which to understand the deep structure and basin geometry of T39/P.

\*SEEBASE™ = Structurally Enhanced view of Economic Basement

## Work Program

In order to obtain seismic data and interpretations to generate an updated SEEBASE™, FrOG Tech spent considerable time negotiating data access with Geoscience Australia, Fugro and Benaris. The following work program was largely dictated by data availability and timing:

1. Geoscience Australia regional public domain 2D seismic data and interpretations obtained from GA and loaded into FrOG Tech workstation.
2. Fugro reprocessed T39/P seismic data obtained from Benaris and loaded into FrOG Tech workstation
3. Benaris T39/P Top + Intra Eastern View interpretations loaded into FrOG Tech workstation
4. FrOG Tech interpretation of top basement and major faults in GA + Fugro seismic, using existing GA interpretation as a guide. Only possible on better quality seismic lines.
5. Depth conversion of seismic basement pick using FrOG Tech’s 2001 time-depth model
5. Enhancement filtering and image processing of FrOG Tech 2001 magnetic grids tailored to T39/P
6. Integrated interpretation of major faults in T39/P based on seismic + magnetics
7. Construction of T39/P SEEBASE™ based on seismic basement picks, 2001 magnetic depth modeling and T39/P structural interpretation
8. Investigation of relationship between deep structure/basin architecture, and possible structural trap fairways at top Eastern View Group level.



## FrOG Tech Methodology

The evolution of sedimentary basins is controlled by a response in the crust and lithosphere to tectonic forces. The nature of this response depends on the magnitude of the tectonic forces, and the character and kinematic response of the underlying basement. The strength, composition and fabric of basement at the time of a tectonic event controls crustal response, while sediments record the resultant changes in basin morphology. A rigorous model for basin evolution can be developed through understanding basement character beneath and adjacent to sedimentary basins, coupled with a knowledge of tectonic events that were responsible for basin formation (i.e. basin phases). This model provides a basis for more accurate prediction of the occurrence and distribution of petroleum play elements throughout basin evolution.

Individual basin phases are separated from one another by changes in the type of subsidence mechanism or the magnitude or rate of subsidence. Basin phase boundaries correspond to plate-scale tectonic events and in turn to major megasequence boundaries. Stresses operating during each basin phase cause 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).

Basement structure in the Bass Basin has proven difficult to interpret as deep basin imaging is limited by poor seismic data quality. **Potential field data** (principally gravity and magnetic data) **provide a window to the basement that can cover a wide area with uninterrupted data at constant resolution**. Such “map view” interpretation contrasts with the “cross section view” interpretation usually carried out in the oil industry.

Once calibrated to geology, potential field data provide information that allows the development of a predictive structural model based on basement composition and structure. Depth to magnetic basement can be modeled from magnetic data and used to produce a structurally-controlled model of basement topography (e.g. SEEBASE™ - Structurally Enhanced view of Economic Basement). Once calibrated with geology, basement structure and topography can be used to predict basement-involved and basement-detached structures, first-order fluid focus points, and the evaluation of source, reservoir and seal quality and distribution throughout the basin. The interpretation techniques and tools are efficient and cost-effective from continental to concession scales.

## Why FrOG Tech?

FrOG Tech is based in Canberra, Australia, and formed in 1997 as SRK Consulting Energy Services. FrOG Tech is a world leader in the systematic calibration, integration and interpretation and non-seismic and seismic datasets in the petroleum exploration industry. The group has completed more than a 100 projects in its main knowledge areas.

FrOG Tech employs a diverse range of highly qualified consultants from both petroleum and minerals backgrounds. Our ability to put together teams with a project-specific skills-base provides innovative, lateral solutions to complex geological issues. In particular, the seamless integration of petroleum and mineral exploration methodologies provides a unique and powerful problem-solving tool for our clients from regional to field-scale and frontier to mature petroleum basins.

The integration of tools from a range of resource sectors provides innovative cost-effective solutions to everyday problems. The same set of tools is applicable to petroleum field development, structural risk mapping in coal mines, for exploration and production of coal seam methane and groundwater studies.

## Importance of Basement

The basement of any basin provides the foundation onto which the sediments are deposited. The rheology or mechanical behaviour of the basement controls the rate of subsidence and geometry of each phase of the evolving basin. The composition of the basement will determine its strength or stiffness. The age and early history of each basement terrane will dictate the intensity and character of the structural fabric. This inherent fabric plays a major role in the manner in which the crust deforms during major periods of extension or compression.

Understanding basement structures allows models to be developed that can predict which structures will reactivate, how they will move under an applied stress, and how they will propagate into the overlying sediment pile. Using plate tectonic reconstructions, the far-field stress state during past events can be estimated and a kinematic reconstruction produced for each event. Since 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 (both basement-involved and basement-detached) in the sediments. In addition, basement topography controls the localisation and geometry of many basement-detached systems.

The faults described in this study have been interpreted primarily using non-seismic datasets and are primarily basement-involved. The reactivation history of these faults reflects the changes in stress regime in the crust in response to specific tectonic events. The resulting event maps show structures at top-basement level interpreted to have been active during that basin phase. The details of the influence of these basement-involved structures on the evolution of structures in the overlying sediments provides the basis for future basin to prospect-scale studies.

By building such a “bottom-up” model for basin evolution, combining it with the “top-down” knowledge generated from seismic and wells, petroleum systems can be better understood and targeted. This approach is described in more detail by Pryer et al (2002) and Teasdale et al (2003).

**The characteristics of basement provide the first-order control on basin architecture with the potential for influencing:**

- ❑ Source rock distribution & volumetrics
- ❑ Heat flow patterns
- ❑ Migration focusing and pathways
- ❑ Trap timing, distribution, type, integrity and size
- ❑ Sediment supply and stratigraphic geometry
- ❑ Distribution and quality of reservoirs and seals



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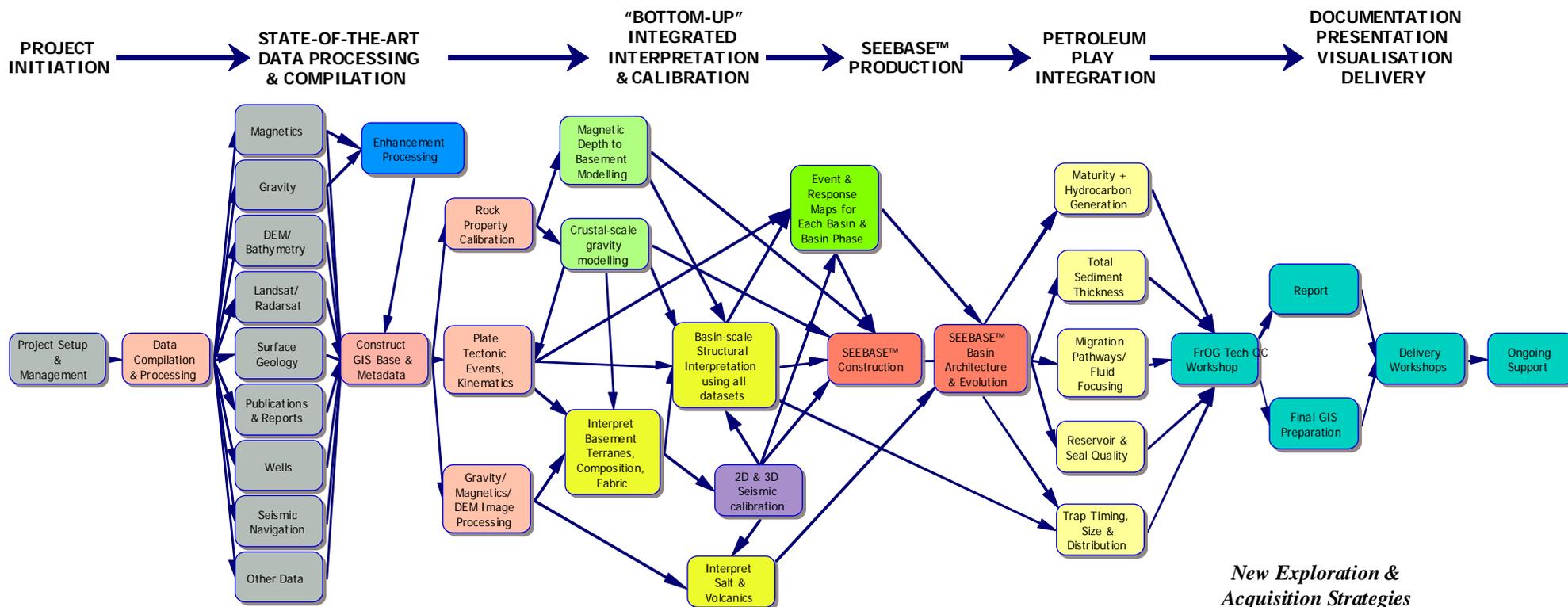
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# The SEEBASE™ Workflow

The key element in developing a SEEBASE™ structural model for basement topography and basin evolution is the integration of all available geological and geophysical information. No individual dataset alone will ever provide as definitive and unambiguous an interpretation as a combination of datasets. Integration provides the means for constraining the interpretation of each dataset. This process ultimately provides the most tightly constrained model result.

Once the interpretation has been calibrated to known geology, a model consistent with all available data can be developed. Then the model can be applied and tested by iterative interpretation and checking against the seismic interpretation. Adjustments are made as needed to both the model and the seismic interpretation with each iteration.

A powerful aspect of the SEEBASE™ workflow is that the interpretation is performed in 2D map view and 3D; a significant departure from conventional seismic-based basin analysis which is largely carried out in 2D cross section view.

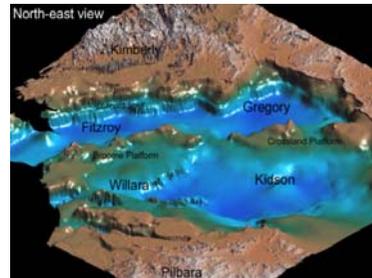
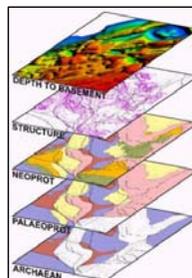
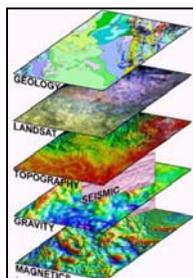


*New Exploration & Acquisition Strategies*

*New Views in Old Basins*

*Efficient & Effective Exploration*

*Play & Prospect Evaluation*



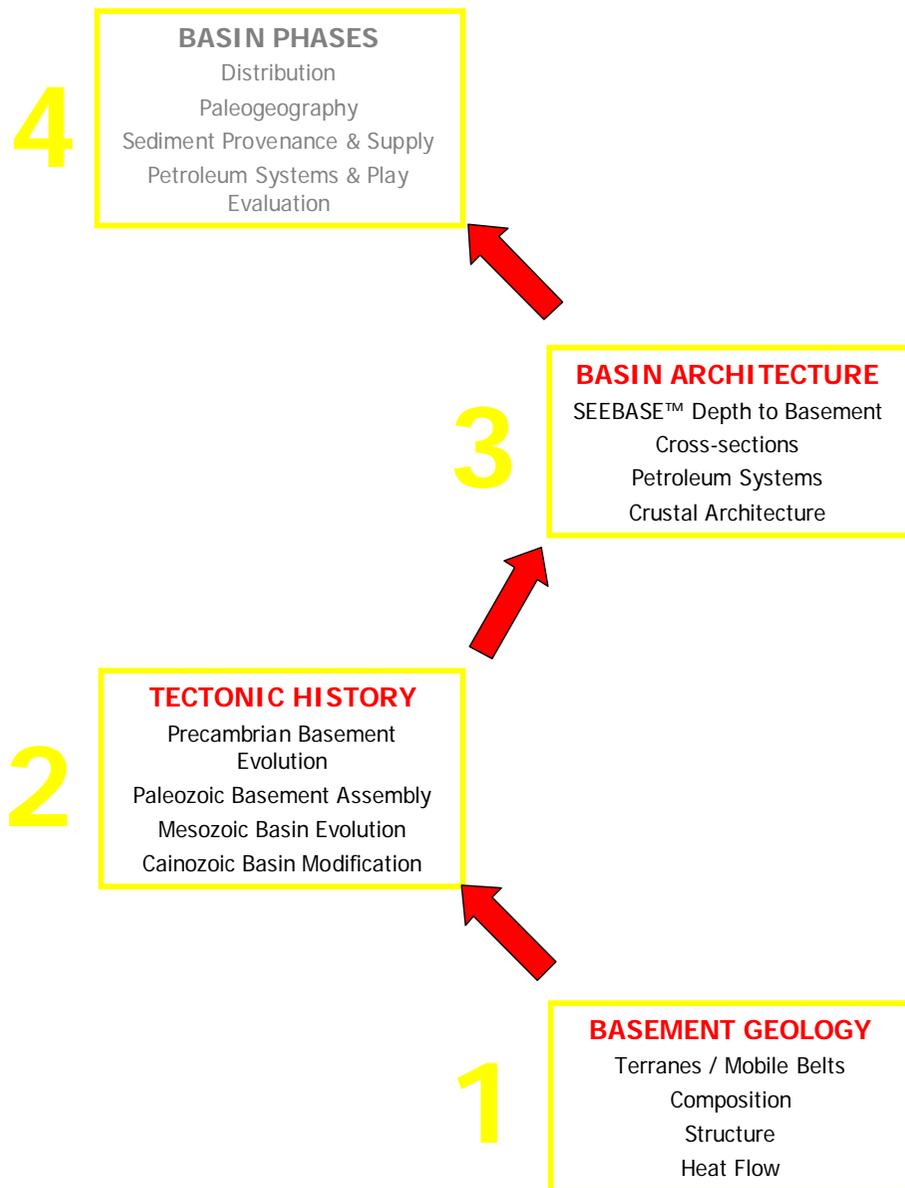
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## FrOG Tech's "Bottom-Up" Basin Analysis



## Data Compilation & Processing

As many datasets as possible were compiled into GIS format for this study. Datasets can be divided into *Core Datasets* (those which are interpreted and integrated in detail) and *Calibration Datasets* (those which are used selectively to constrain the interpretation). Our interpretations are based largely on potential field data (i.e. gravity and magnetics), since these data provide the most continuous coverage in the map view. The interpretation should be updated as new datasets become available.

### Core Datasets

**Magnetics** 2001 stitched magnetic grid (see Teasdale et al, 2001)  
**2D seismic** GeoQuest projects (GA + Fugro)

### Calibration Datasets

**Wells** location, formation tops, basement penetrations etc.  
**Sequence stratigraphy** stratigraphic charts, paleogeography, tectonostratigraphy  
**FrOG Tech regional knowledge-base** reports, intellectual property  
**Publications, papers, maps, cross sections** extensive reference list – especially recent GA publications (e.g. Blevin et al, 2005)

The following section outlines the datasets used for this project, and their processing history.

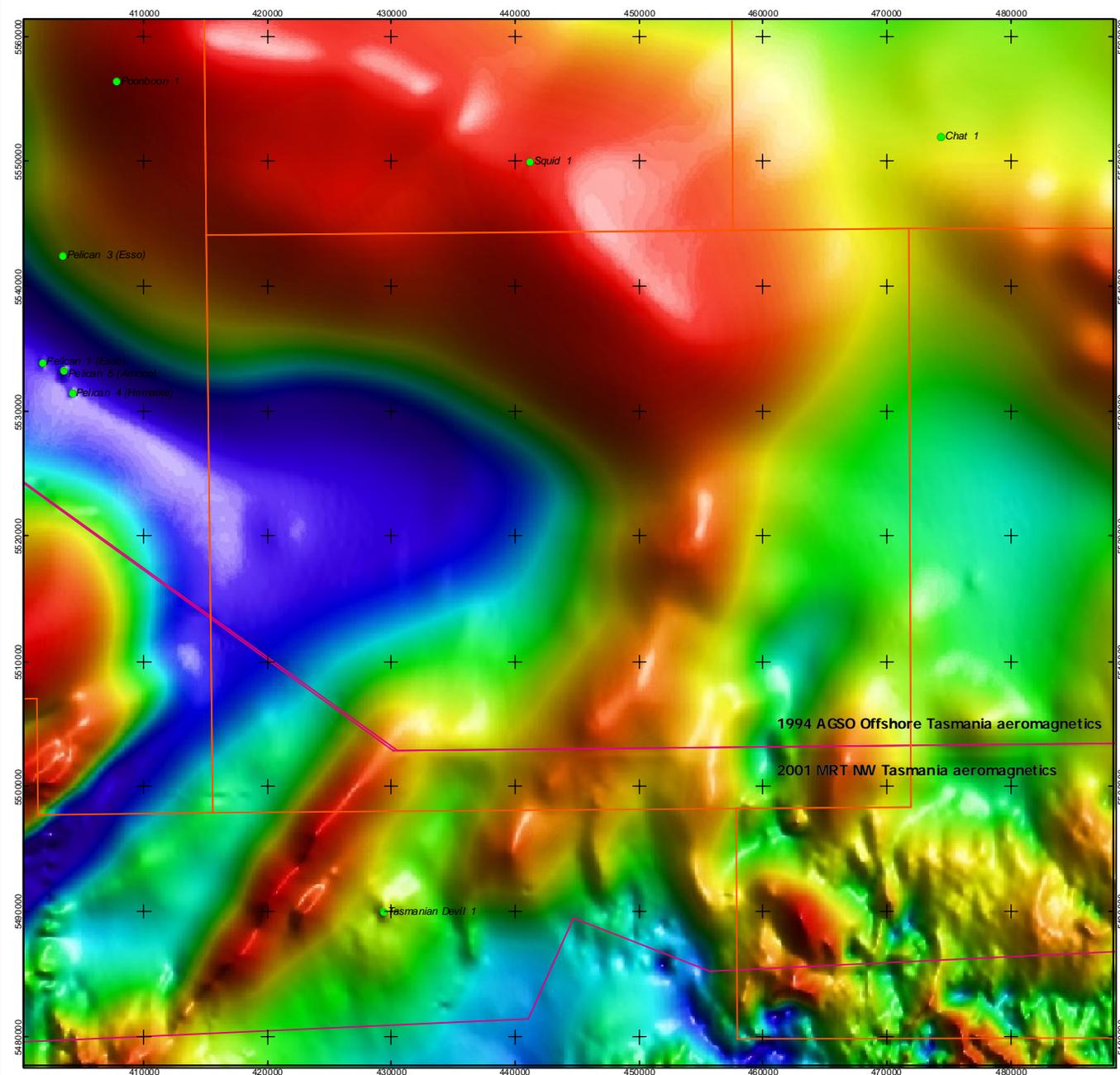


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# Bass Basin Total Magnetic Intensity (TMI)



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 magnetic basement and intrasedimentary magnetic units (if present). Most bodies within basement have a distinctive magnetic signature which is characterized by the magnitude, heterogeneity and fabric of the magnetic signal. When calibrated with known geology, basement terranes can be mapped under a cover of sedimentary rock, regolith, water or ice.

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 gravity data, a model for the evolution of the basement and overlying basins can be developed.

For this project, FrOG Tech used the enhanced stitched magnetic grids developed during the Bass Basin SEEBASE™ Study (Teasdale et al, 2001). Two magnetic surveys cover T39/P:

- (i) 1994 AGSO Offshore Tasmania high resolution aeromagnetic survey (400m line spacing)
- (ii) 2001 MRT NW Tasmania high resolution aeromagnetic survey (200m line spacing)

The subsequent pages show key images selected by FrOG Tech's interpreters for structural + basement interpretation.

A Total Magnetic Intensity (TMI) image of this survey is shown opposite. TMI images are the most basic form of magnetic data display after correction for diurnal variation and levelling of the data corrected from the original data source.

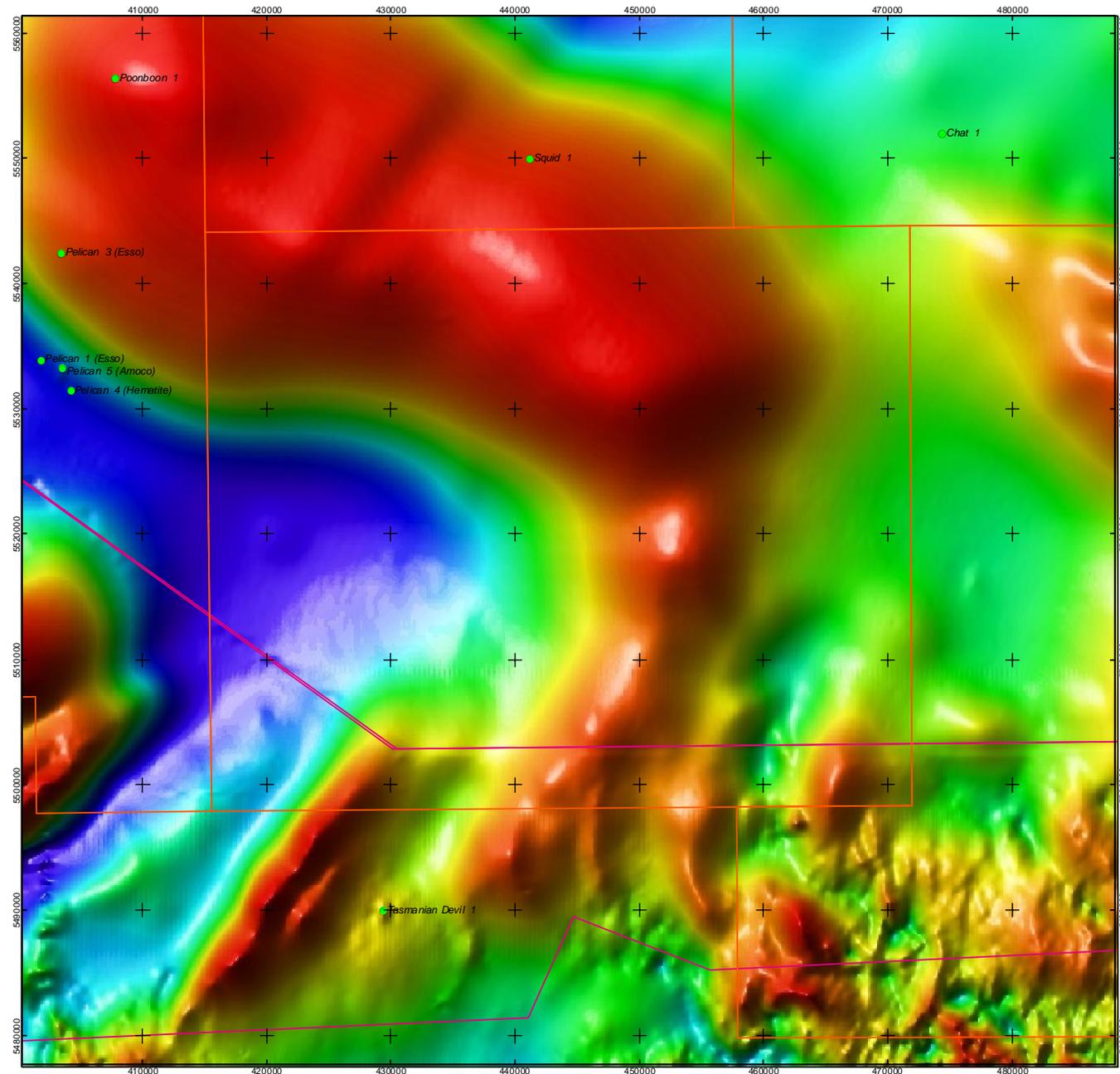


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## TMI Reduced to the Pole (RTP)



Reduction to the pole (RTP) is a manipulation of the magnetic anomalies to represent them as if they were generated in a vertical field (i.e. magnetic inclination of  $90^\circ$ ). Magnetic inclination in this area is approximately  $60^\circ$  so the RTP process subtly affects the dataset (e.g. central magnetic high shifted  $\sim 5\text{km}$  to the south by RTP process). RTP grids are easier to interpret than the TMI because they place anomalies directly above the source of the magnetic field, however, some artificial  $\sim\text{N-S}$  trends at the northern and southern extremes of the dataset are often introduced. Care must also be taken interpreting N-S-trending features elsewhere in the data.



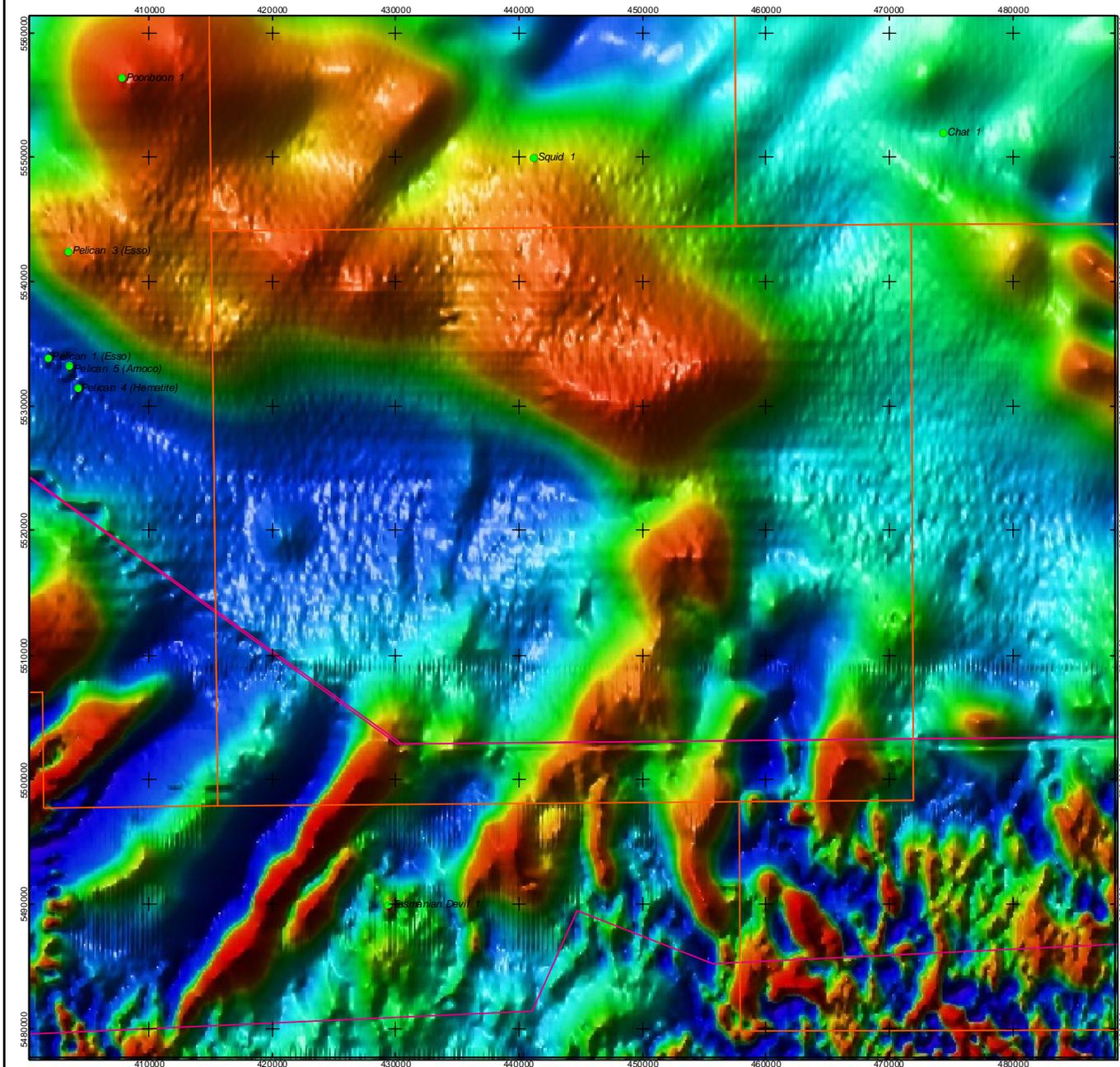
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## First Vertical Derivative of RTP



A first vertical derivative (FVD) is applied to the RTP grid to remove the effects of very regional magnetic anomalies that would come from deep crustal or mantle sources. The FVD filter enhances magnetic anomalies caused by shallow sources and by the top parts of deep, or large depth extent, bodies. Anomaly peaks can be used to locate the centres of magnetic sources or the steeper sides of magnetic bodies. The zero contour lines can be used to locate boundaries of magnetic sources. The Bass Basin FVD grid contains a moderate amount of acquisition and stitching noise. Further processing of the raw magnetic data is required to remove this noise.



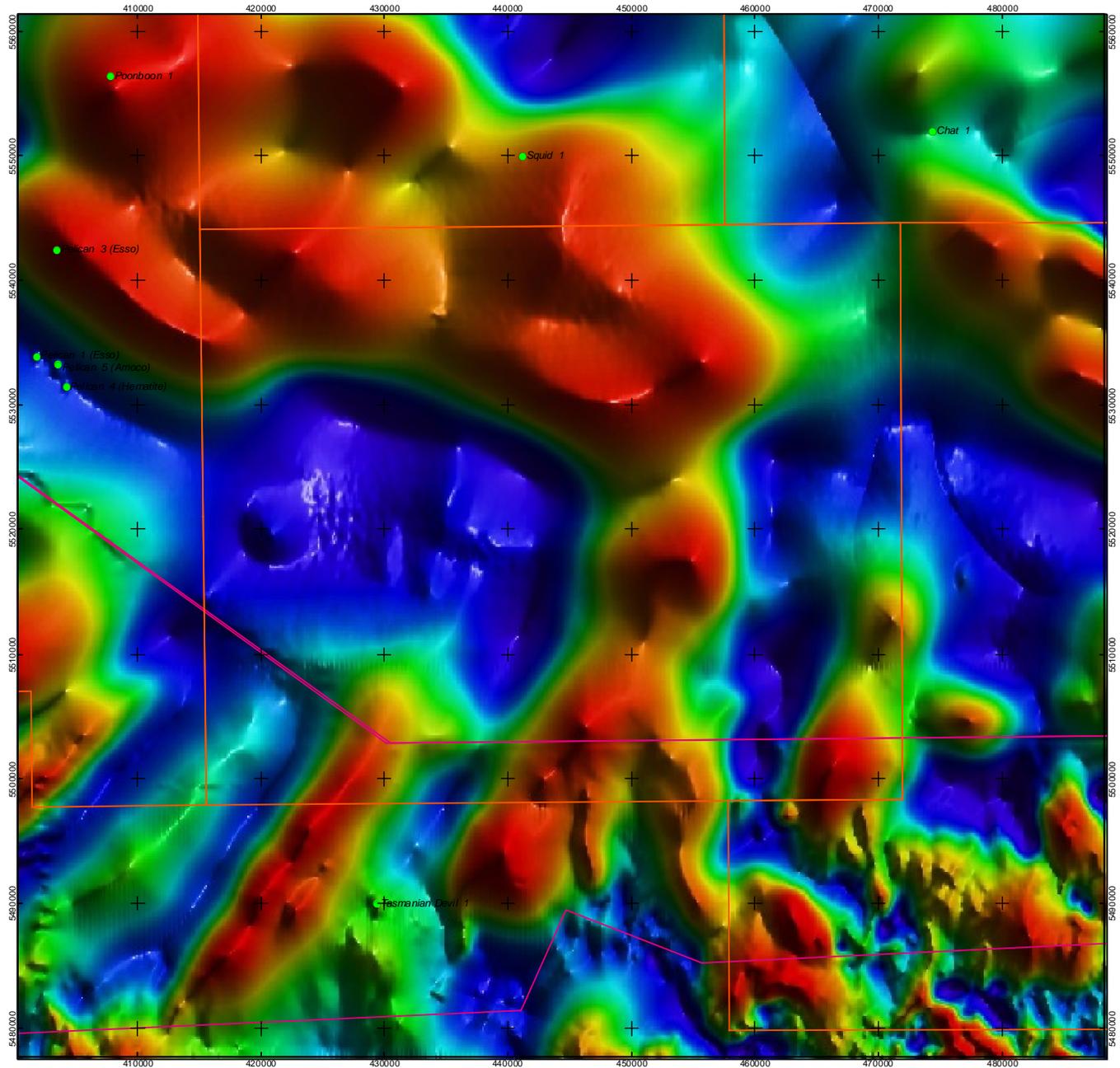
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# Automatic Gain Control of RTP (AGC)



Automatic gain control (AGC) filters reduce the amplitude variation of magnetic anomalies and enhance anomalies in areas of minimal magnetic variation.



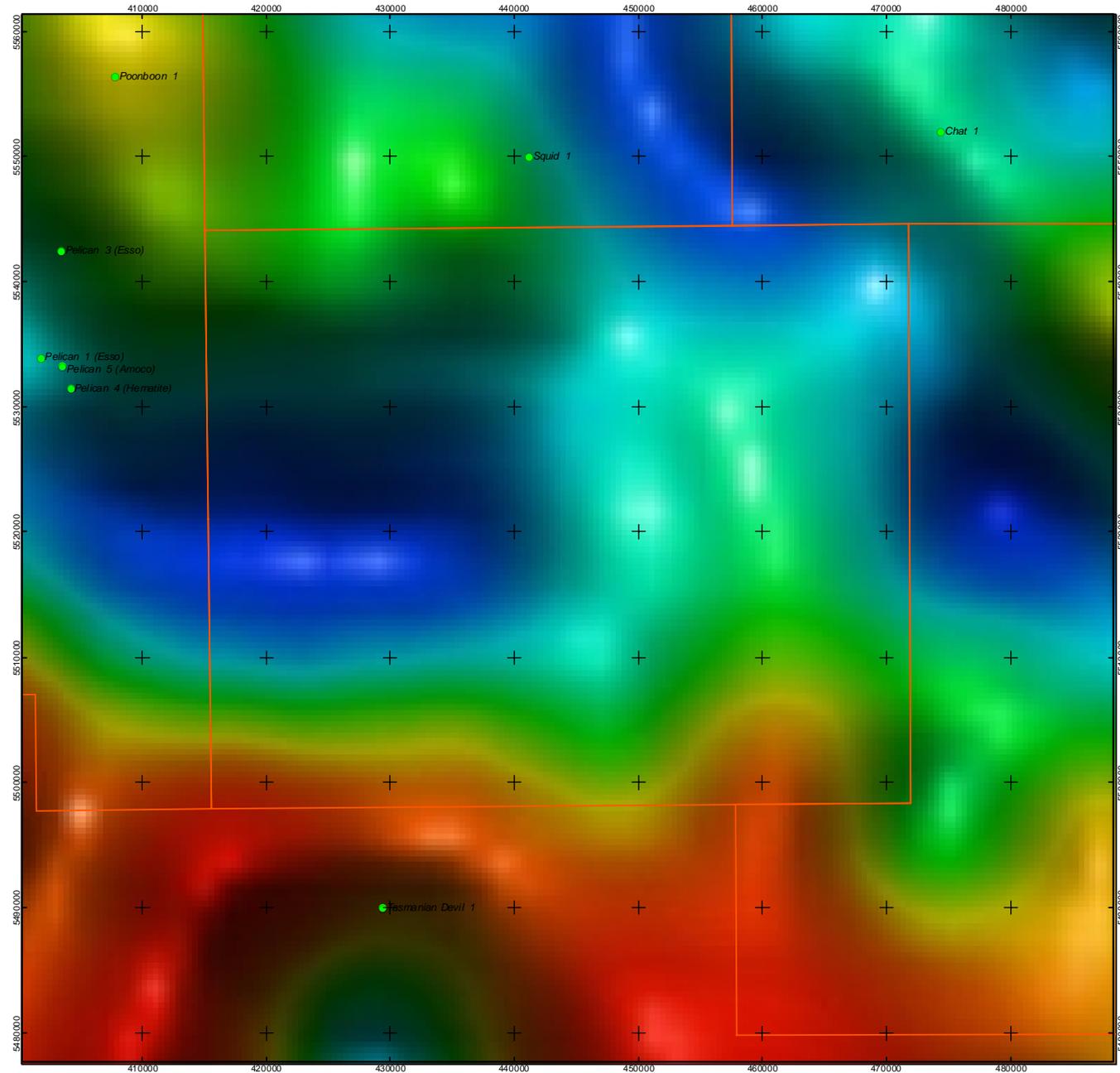
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# Gravity



This gravity image is generated from FrOG Tech's isostatic residual magnetic grid of Australia. Gravity data in the Bass Strait is coarsely spaced and does not permit structures to be directly interpreted, however the image shows the broad distribution of basin troughs and basement highs.



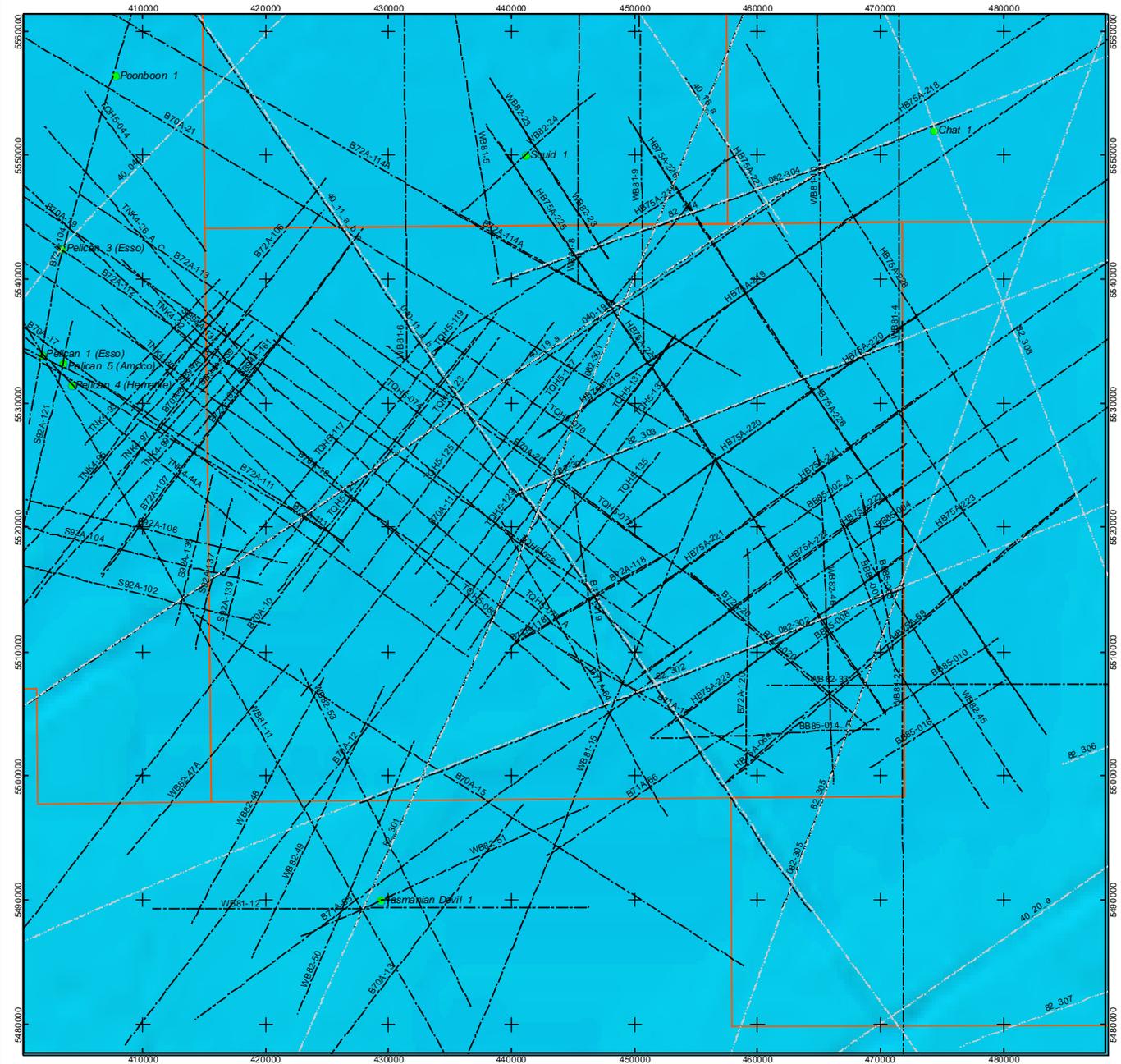
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# Bathymetry, Seismic, Wells



Bathymetry data for the Bass Basin shows almost flat, shallow (<200m) sea floor topography in T39/P.

Seismic data used in this study includes confidential reprocessed data from Fugro (black lines, supplied by Benaris), as well as regional public domain data from Geoscience Australia (grey lines). Data quality is highly variable.

No wells have been drilled in T39/P. Wells near T39/P include Pelican wells, Squid 1, Tasmanian Devil 1 and Chat 1.



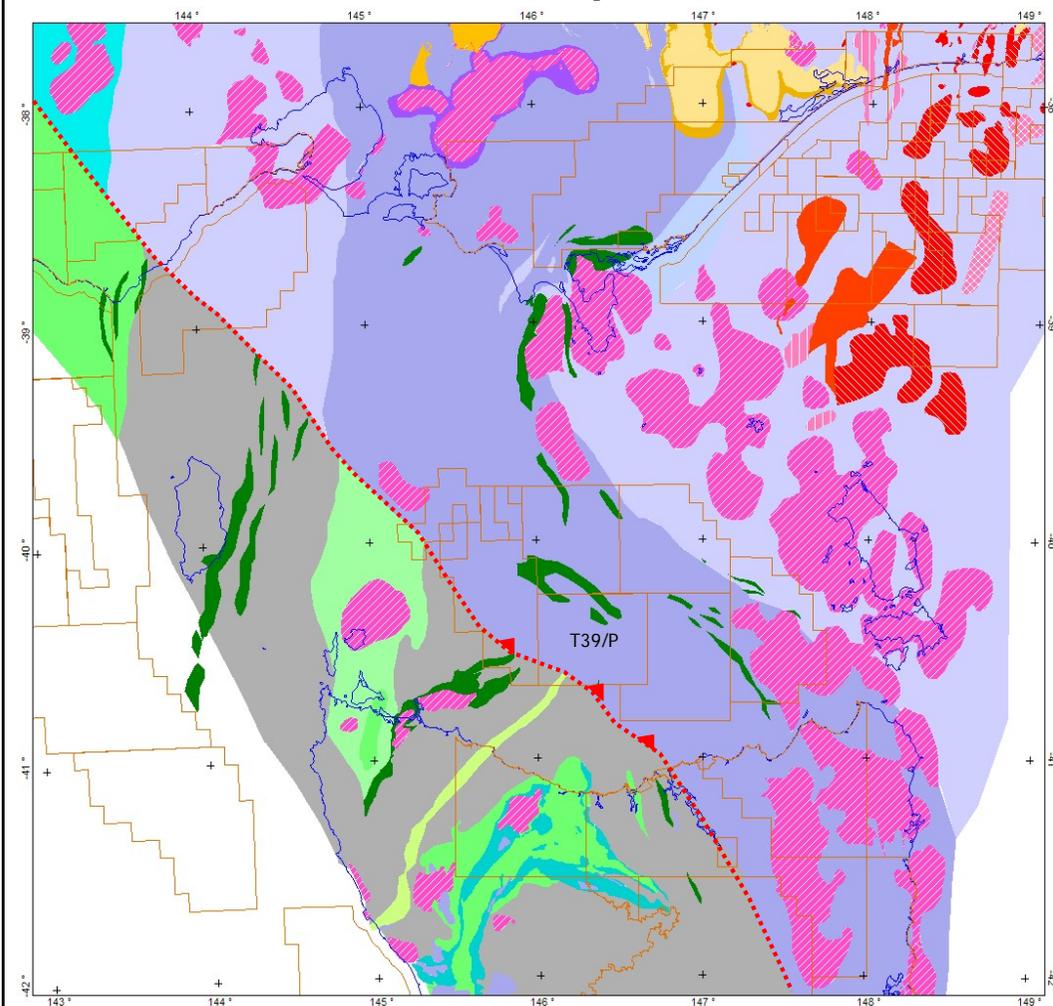
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# Basement Terranes & Composition



### Legend

- |                                    |                                |                       |
|------------------------------------|--------------------------------|-----------------------|
| Late Devonian-Carb sediments       | Siluro-Devonian seds           | <b>Granites</b>       |
| Late Devonian volcs                | Ord metamorphics               |                       |
| Early Devonian volcs + sediments   | Ord-Early Sil seds             |                       |
| Upper Devonian metamorphic aureole | Cambrian greenstone belts      |                       |
|                                    | Latest Neoprot sediments       |                       |
|                                    | Neoproterozoic (meta)sediments |                       |
|                                    |                                | Mid to Upper Devonian |
|                                    |                                | Lower Devonian        |
|                                    |                                | Siluro-Devonian       |
|                                    |                                | Lower Silurian        |

The basement composition interpretation presented here is taken directly from Teasdale et al (2001).

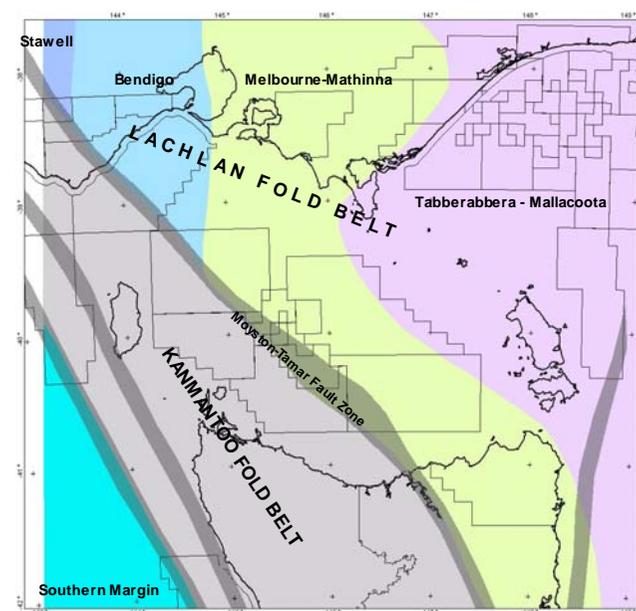
The Bass Basin overlies two key basement terranes: the Kanmantoo and Lachlan Fold Belts. Cambrian platform sequences, turbidites and volcanics were deposited and deformed on the extended Proterozoic margin of Gondwana, forming the Kanmantoo Fold Belt.

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, and runs through Benaris’ T39/P. In T39/P this terrane boundary is interpreted as a shallowly NE-dipping structure (?suture); hence the NE-trending structural grain of the Kanmantoo Fold Belt influences T39/P to the SW of the terrane boundary as drawn here (in the footwall of the terrane boundary).

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.



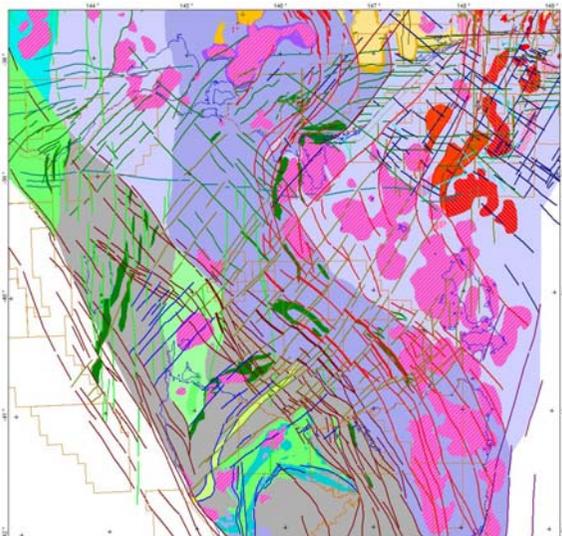
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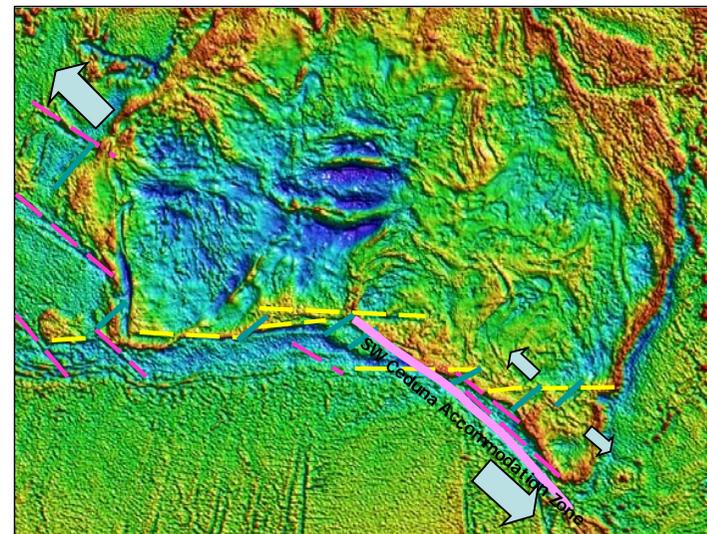
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# Bass Basin Tectonic Evolution Summary

(See Teasdale et al, 2001; 2003 for more detailed discussion)



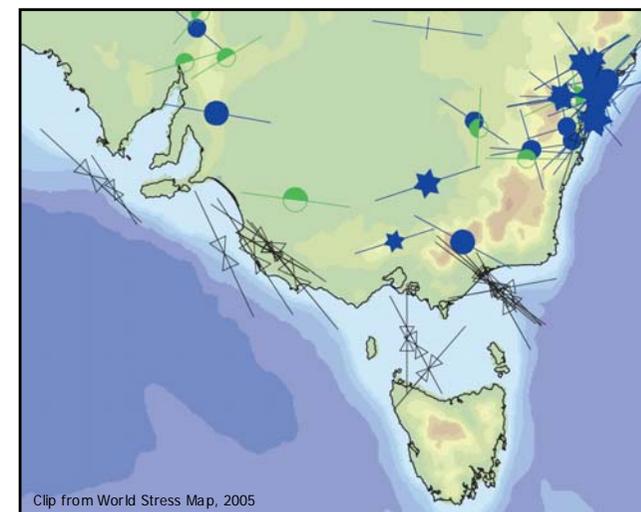
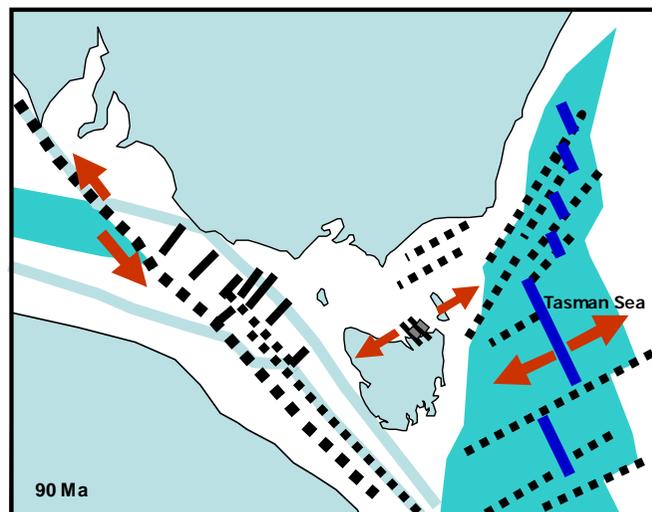
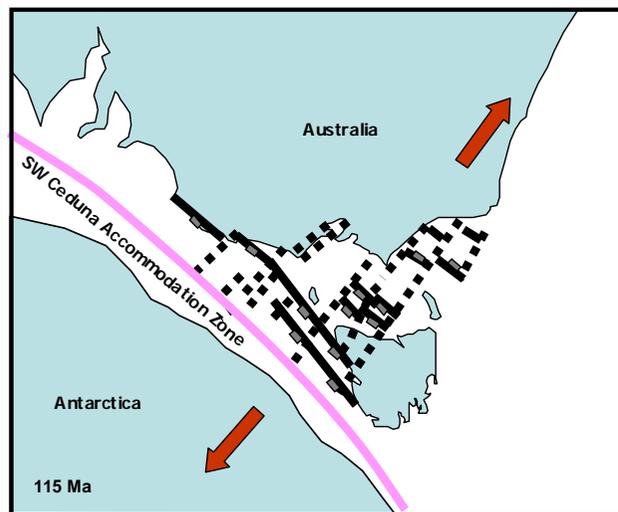
CENOZOIC	TERTIARY	QUATERNARY			
		PLIOCENE			
		MIOCENE	BASIN PHASE 7	Ecene-Recent Platformal Sag Subtle Mid-Late Miocene inversion	
	TERTIARY	OLIGOCENE			
		EOCENE	BASIN PHASE 6	Early Eocene Inversion	
	TERTIARY	PALEOCENE	BASIN PHASE 5	Late Cretaceous - Early Tertiary Sag	
			BASIN PHASE 4	Late Cretaceous Extension	
MESOZOIC	CRETACEOUS	LATE	BASIN PHASE 3	Mid-Cretaceous Inversion	
		EARLY	BASIN PHASE 2	Early Cretaceous Extension - Main rifting & sedimentation in Bass Basin	
	JURASSIC	LATE	BASIN PHASE 1	Late Jurassic Extension - Minor sedimentation & normal faulting in Bass Basin? Significant rifting & sedimentation in Otway & Gippsland Basins.	
		MIDDLE			
		EARLY			



**Neoproterozoic - Paleozoic**  
Evolution of SE Australia basement terranes at active E margin of Gondwana (see Teasdale et al, 2001 for details). Development of NE+NW trending basement fabrics in T39/P.

**Mesozoic - Recent**  
Up to 7 basin phases involved in formation of Bass Basin.

**Late Jurassic – Early Cretaceous (~145-120Ma)**  
Onset of Southern Margin rifting. Possible early transtensional rifting in Bass Basin (no hard evidence of this event to-date).



**Early Cretaceous (~120-100Ma)**  
Main rifting event in Bass Basin. ~NE-SW extension. Formation of major NW-trending half-graben (e.g. Pelican Trough), compartmentalized by major NE-trending accommodation/transfer zones.

**Late Cretaceous (~90-80Ma)**  
Opening of Tasman Sea. ~ENE-WSW extension. Formation of new half-graben in Bass Sea (e.g. Durroon Trough) + oblique reactivation of Early Cretaceous half-graben.

**Mid-Late Miocene**  
Present-day stress data for SE Australia suggests Bass Strait area under approximately N-S to NNW-SSE compression. This stress regime is likely to be representative of the Mid-Late Miocene stresses that caused subtle inversion of major basin-bounding structures in the Bass Basin, forming potential hydrocarbon traps.

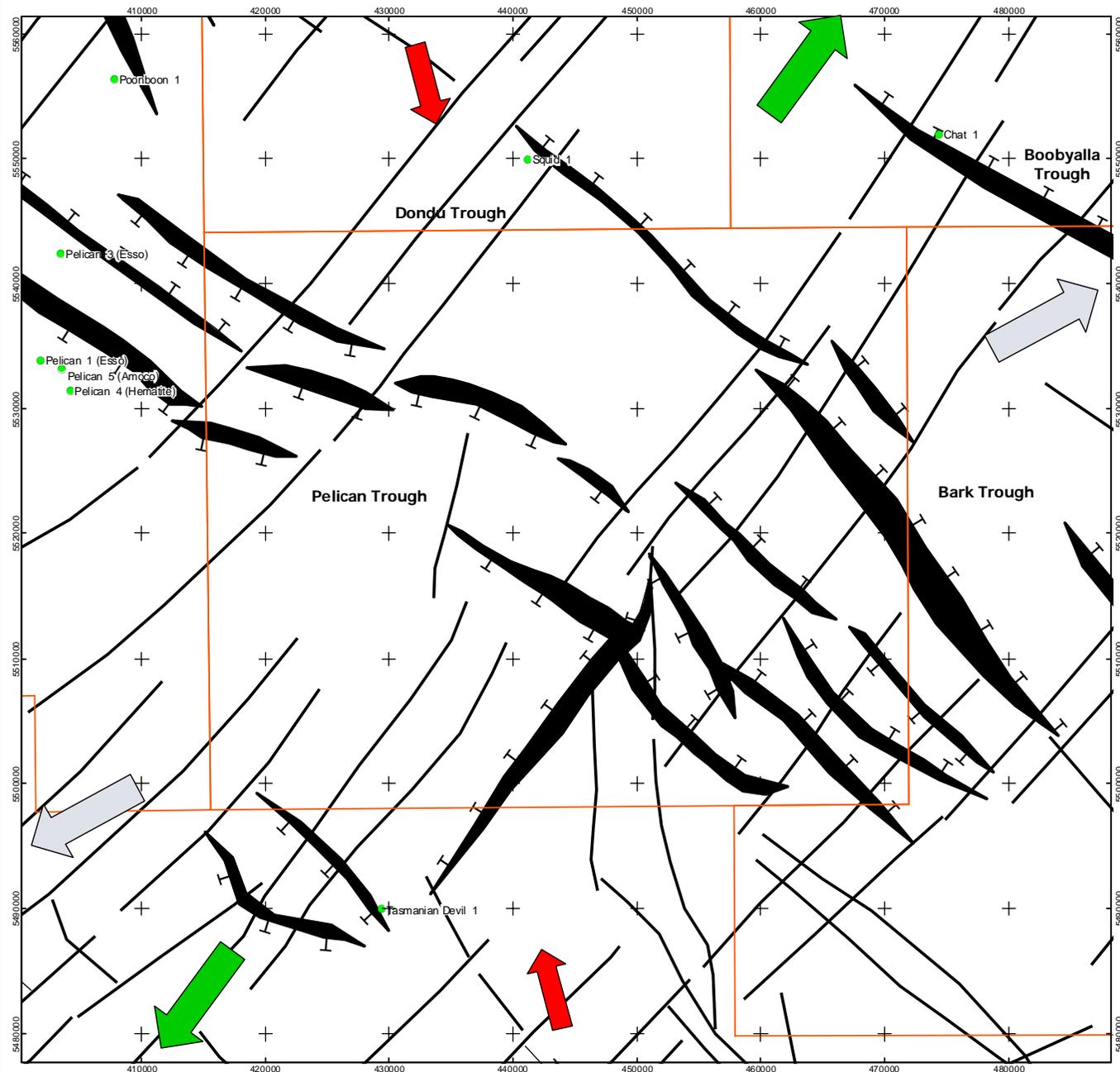


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# T39/P Structural Interpretation



- This map shows major basement structures interpreted to have been active during the two Cretaceous rift events in the Bass Basin.
- Structures were interpreted using a combination of magnetic, gravity and seismic data.
- Reactivation kinematics of each structure can be predicted from the implied stress directions during each basin phase.
- There are some uncertainties regarding the position and existence of the structures shown here due to poor quality datasets.
- All structures interpreted here formed during Neoproterozoic-Paleozoic basement evolution, and have been reactivated to form the Bass Basin.
- Three periods of structural reactivation are inferred (see arrows on map):

1. ~120-100Ma Early Cretaceous NE-SW rifting, forming main bounding faults of Pelican and Dondu Troughs. Present-day architecture of the Bass Basin was established during this event.
2. ~90-80Ma Late Cretaceous ENE-WSW “Tasman Sea” rifting, forming the Durroon Sub-basin (Bark + Boobyalla Troughs). Oblique reactivation of Early Cretaceous rifts to W (e.g. Pelican Trough).
3. Subtle, ~15-8Ma, ~NNW-SSE-directed Mid-Late Miocene inversion of appropriately oriented basement structures (e.g. NW-trending normal faults bounding Pelican Trough).

### Legend

-  ~ 120-100Ma Early Cretaceous rifting
-  ~ 90-80Ma Late Cretaceous rifting
-  ~ 15-8Ma Mid-Late Miocene inversion



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## T39P SEEBASE™

### What is SEEBASE™\*?

SEEBASE™ is a depth-to-basement interpretation that represents the culmination of a number of calibration and integration steps:

- Integrated structural/kinematic interpretation of basement and basin(s)
- 2D and/or 3D geophysical modelling using magnetic and gravity data
- Basement well calibration and seismic basement interpretation (if available)
- Integration of tectonic events & responses

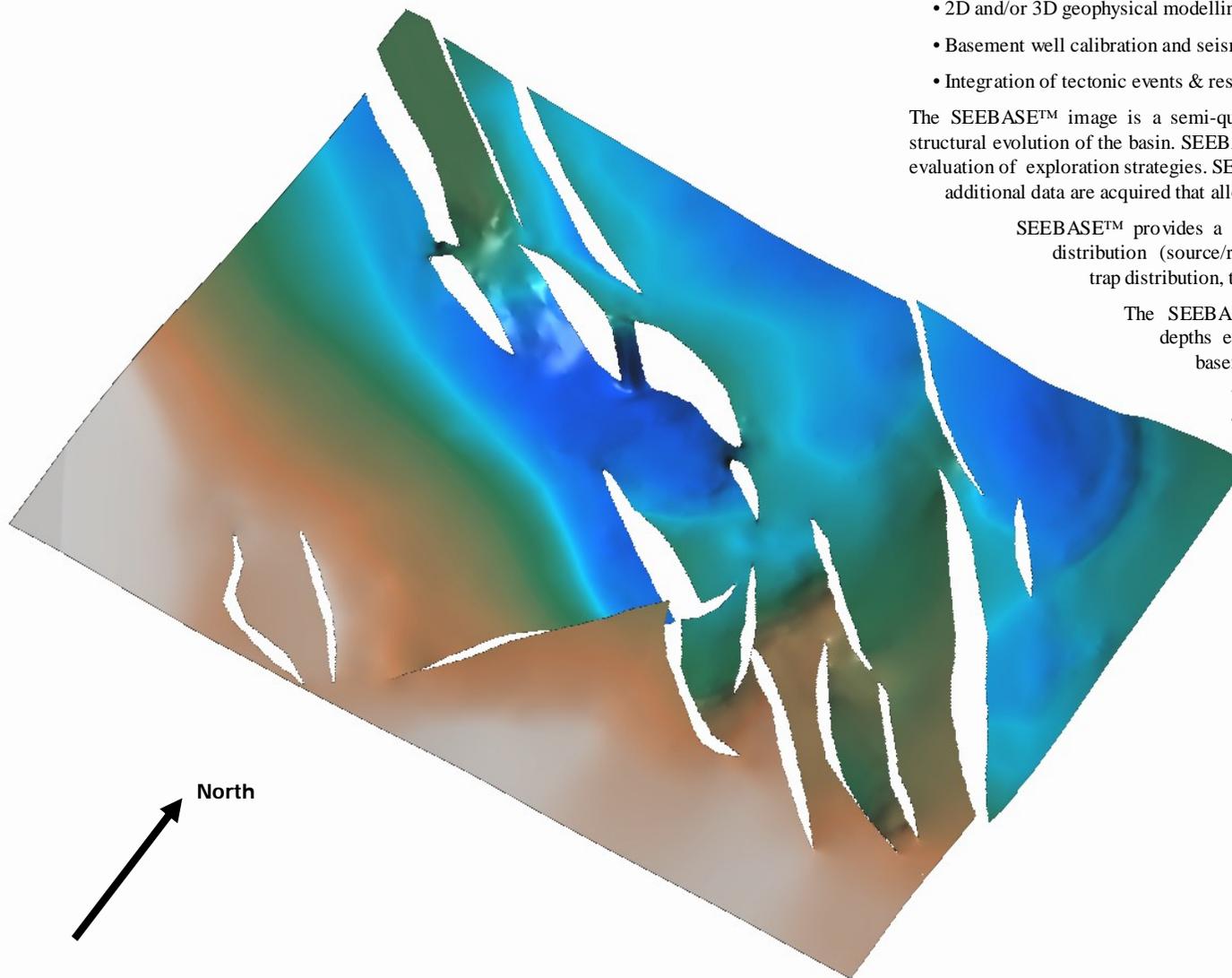
The SEEBASE™ image is a semi-quantitative model of basement topography that is consistent with the structural evolution of the basin. SEEBASE™ defines basin architecture, and forms the basis for the systematic evaluation of exploration strategies. SEEBASE™ can be updated to reflect all new information as additional data are acquired that allow more precise calibration.

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.

The SEEBASE™ basement model is constrained by many datasets, including depths extracted from modelled profiles of magnetic line data, gravity data, basement penetrations in wells and seismic-based depth estimates (if available). The geometry of the basement contours, from which the final grid is produced, is also constrained by a structural model developed from interpretation of all available data.

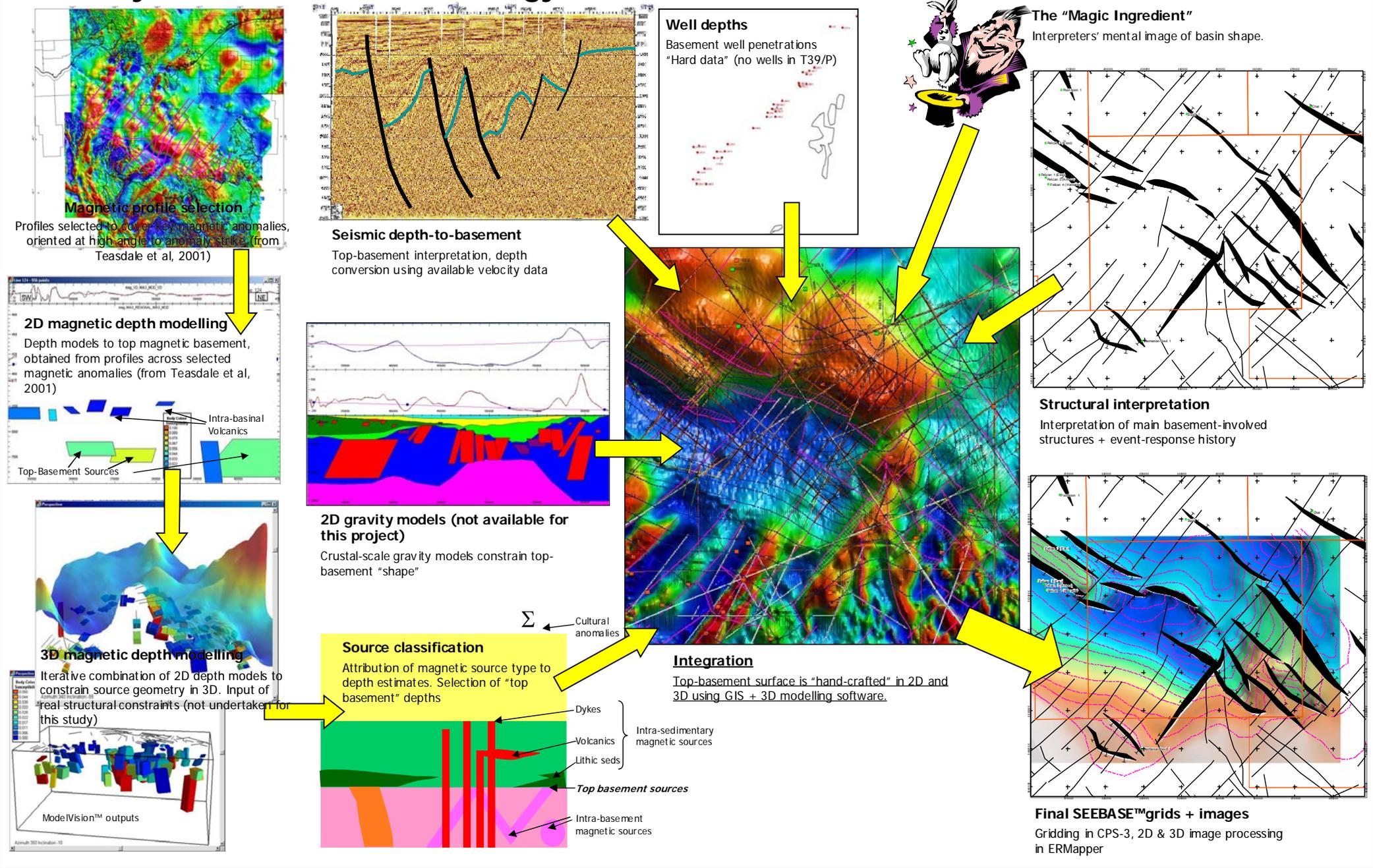
In many parts of the study area, there are limited data to constrain absolute depths. Relative changes in depth are real, but in areas where the basement is very deep and depth constraints are rare, the absolute depth has been estimated. Deep seismic reflection and refraction data, where available, may provide more accurate estimation of depth in basin depocentres. Even without absolute depth constraints, however, the SEEBASE™ image provides a geologically constrained, predictive model of basin shape and structural architecture for petroleum exploration.

It is important to remember that the SEEBASE™ workflow is not a “black box” approach, and involves a number of input datasets that are interpreted to create the SEEBASE™ surface.



\*SEEBASE™ = Structurally Enhanced view of Economic Basement

# Summary of SEEBASE™ Methodology



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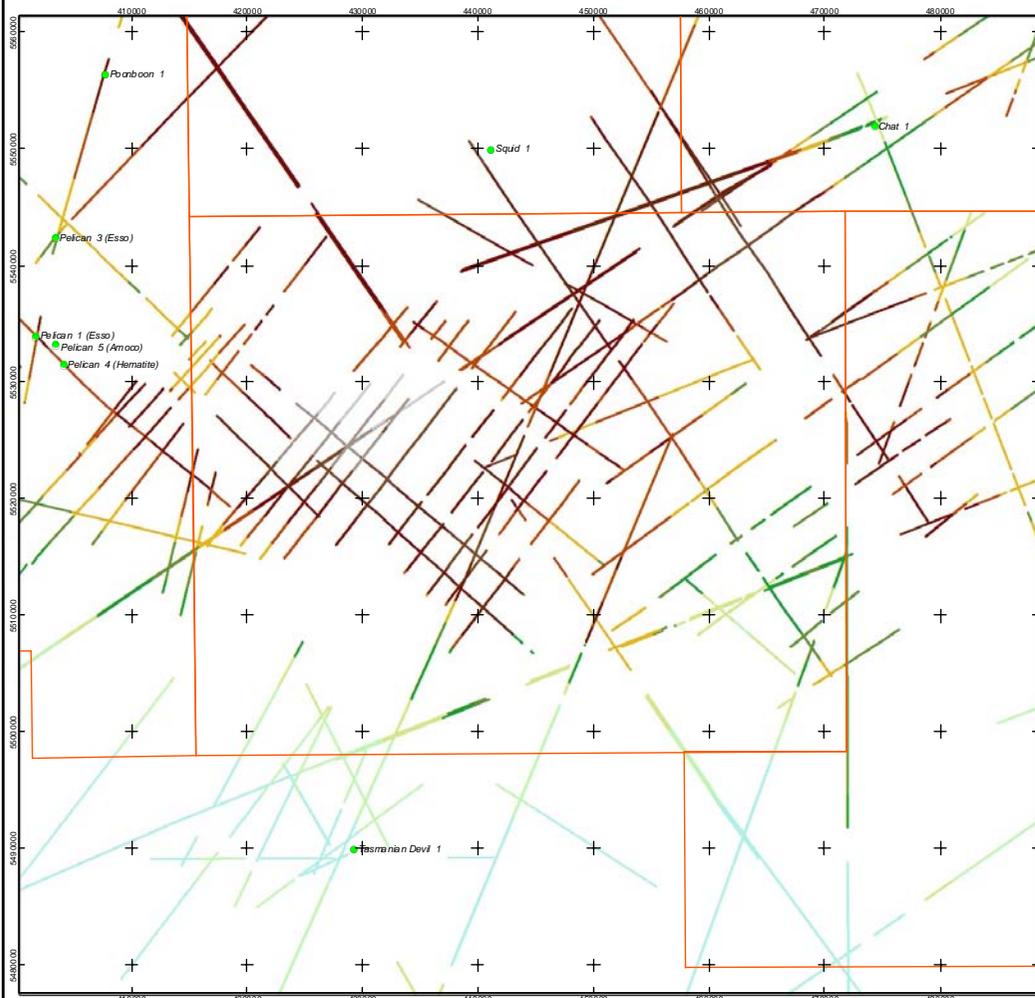
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# T39/P Seismic Basement Mapping

## Seismic Depth to Basement Points

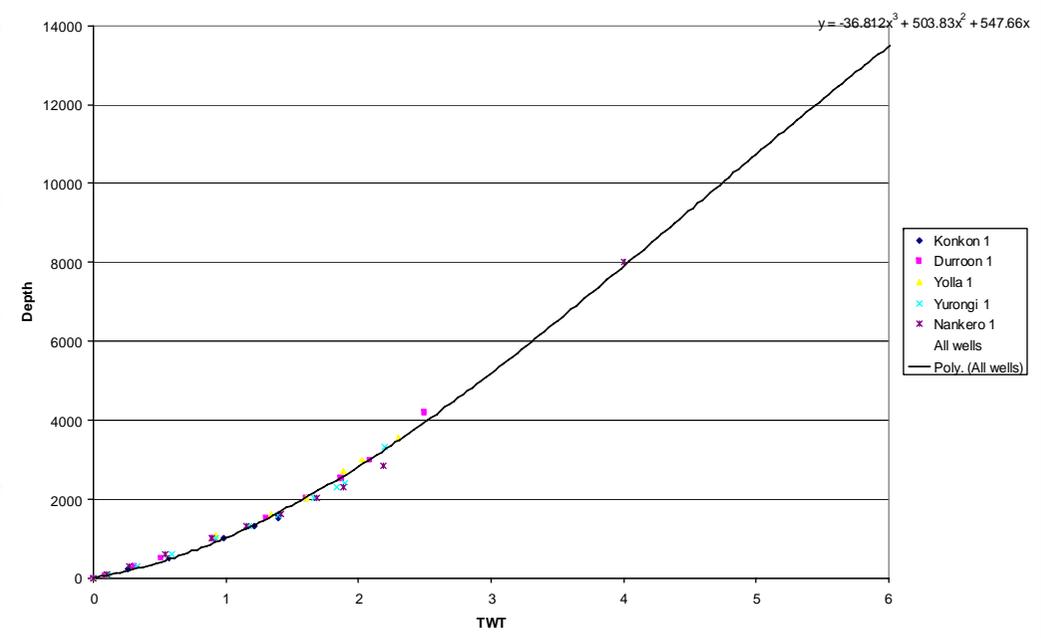


**Depth (metres):**

142.11 - 1000.00	6000.01 - 7000.00
1000.01 - 2000.00	7000.01 - 8000.00
2000.01 - 3000.00	8000.01 - 9000.00
3000.01 - 4000.00	9000.01 - 10000.00
4000.01 - 5000.00	10000.01 - 11000.00
5000.01 - 6000.00	11000.01 - 12000.00
	12000.01 - 13000.00

- Extensive seismic interpretation of top-basement was undertaken to provide input into the T39/P SEEBASE™.
- Top-basement picks were made (where possible) using Benaris' T39/P seismic project (Fugro reprocessed data) + Geoscience Australia's seismic data and interpretations.

## Time-Depth Conversion



- Time-depth conversion derived from sonic logs from selected wells by Teasdale et al (2001), and was used to depth convert seismic top-basement picks.

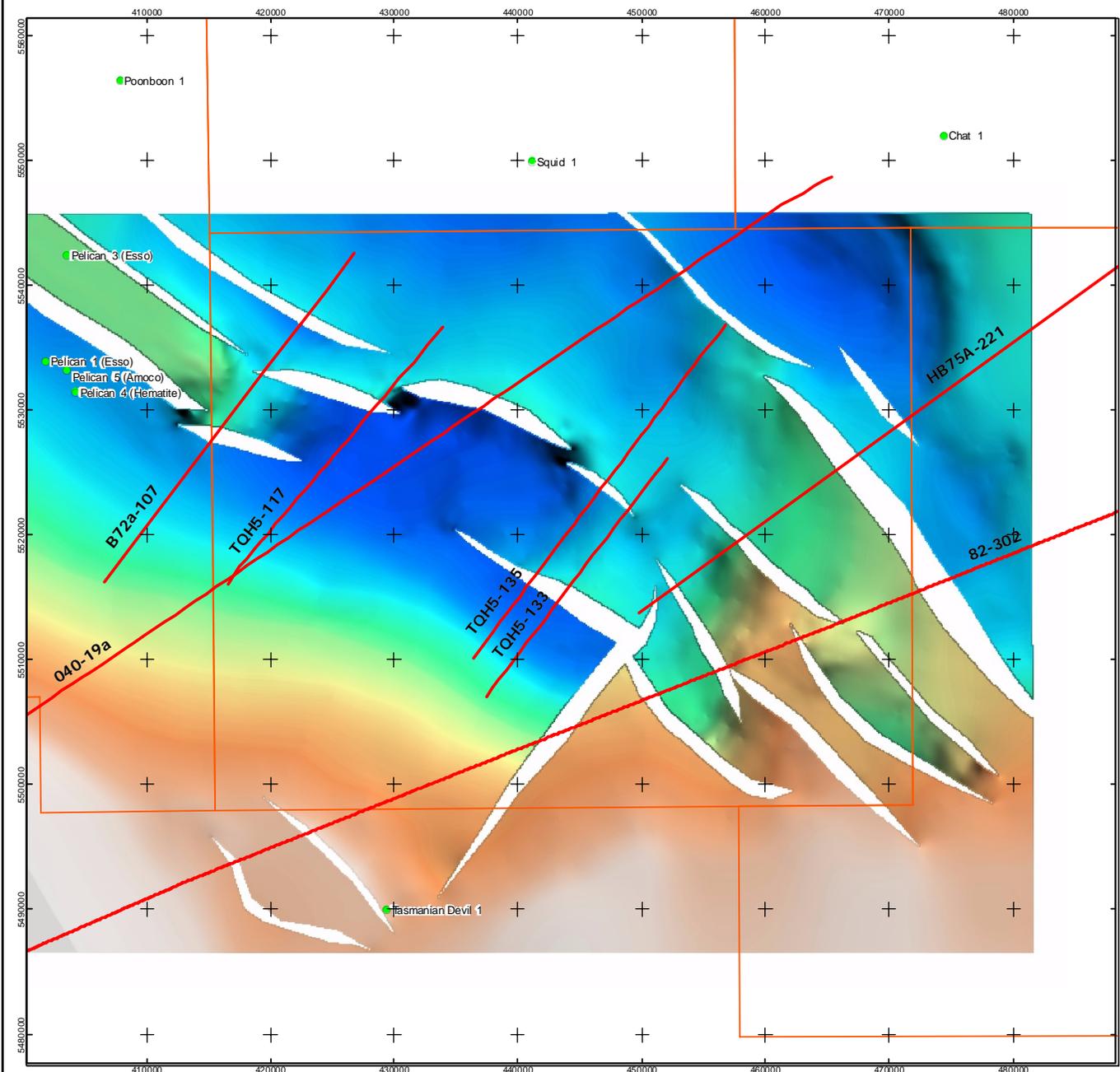


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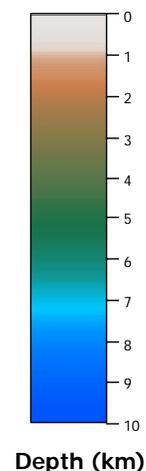
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# T39/P SEEBASE™



- The T39/P SEEBASE™ maps depth to top economic basement, which in this area corresponds to top-?Carboniferous (metamorphic) basement. Since there are no Permian-Early Jurassic sediments interpreted in this area, this SEEBASE™ maps base Bass Basin syn-rift.
- The SEEBASE™ shows the architecture of the Bass Basin in T39/P, and is consistent with our structural interpretation, magnetic depth to basement models, and seismic top-basement interpretation. There are no basement well penetrations in this area.
- It is important to remember that SEEBASE™ is an interpretive product, therefore contains inherent uncertainties. We estimate absolute depth uncertainties of up to  $\pm 20\%$  in this area.
- The SEEBASE™ product is available in image and grid format (see accompanying digital data in ArcGIS format).
- 7 examples seismic lines were selected for this report. Seismic locations are shown overlying the T39/P SEEBASE™ on the adjacent map, and screen captures are shown on the following pages.



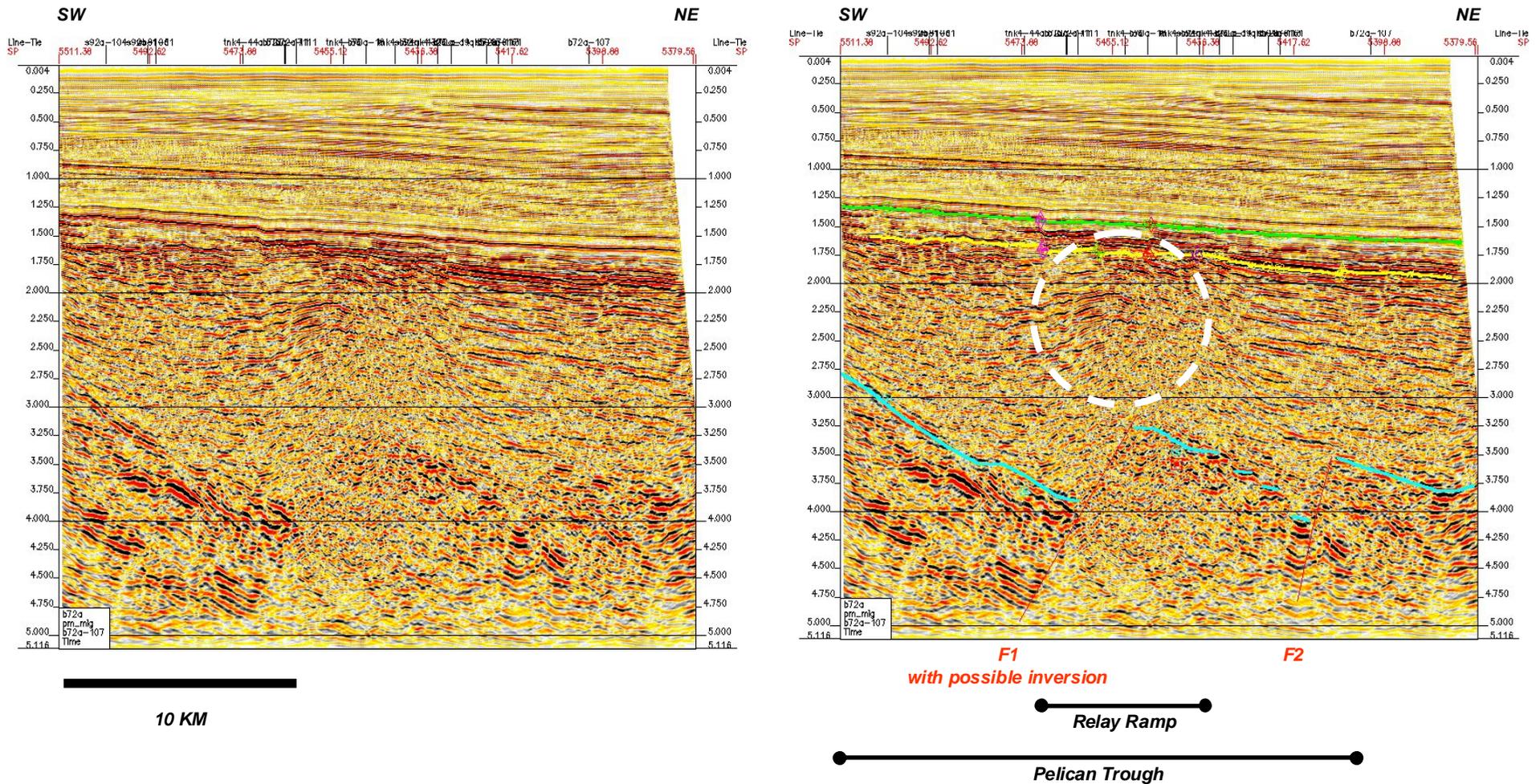
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# T39/P Seismic Basement Mapping

**B72A-107 – Relay ramp between adjacent Pelican faults with inversion in younger sediments.**



- Pelican wells sited on F1 to west.
- Separate fault in prospect area, see map view.
- Inversion over hanging wall of F1



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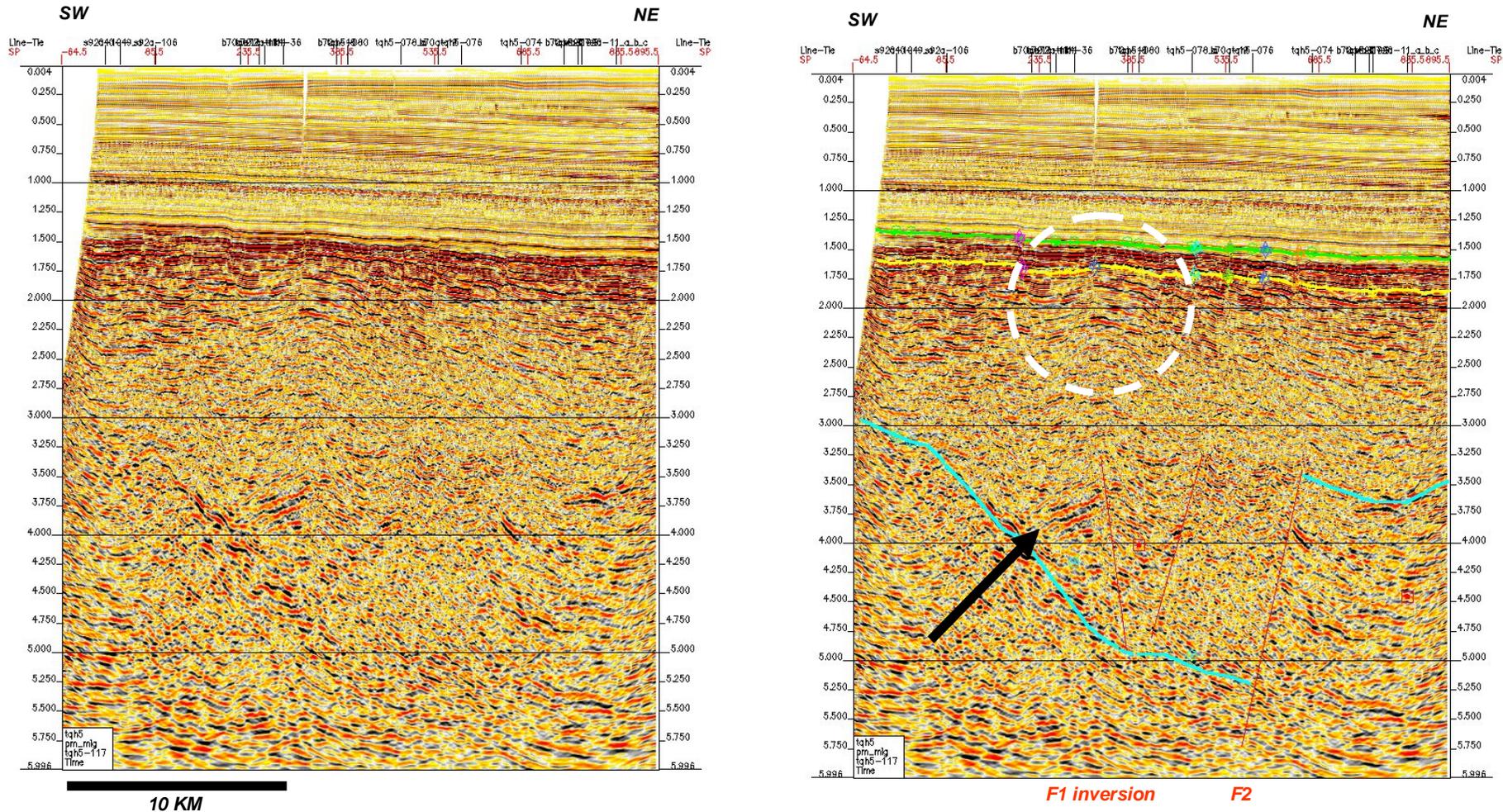
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# T39/P Seismic Basement Mapping

## TQH5-117 – Eastern end of relay ramp, throw transferred to single fault to NE.



- Throw transferred to F2.
- F1 inversion still evident.
- Doming at depth (arrow) may be the result of changes in depocentre geometry due to basement block rotation during fault reactivation.
- Basin boundary fault SW dipping in Pelican Trough



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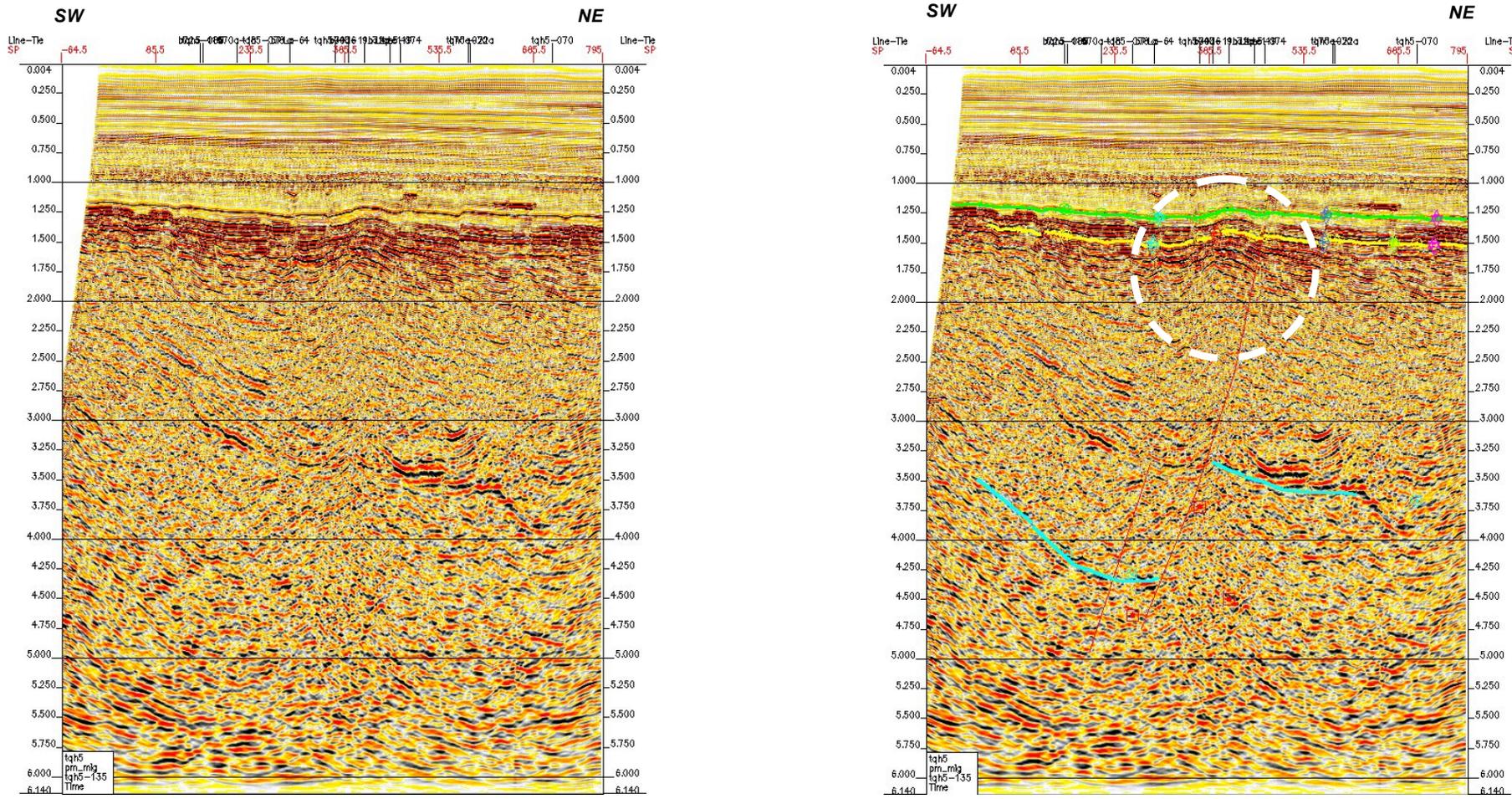
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# T39/P Seismic Basement Mapping

## TQH5-135 - Potential inversion nucleated over internal faulting in Pelican Trough



• "PJ" Prospect in white dashed circle



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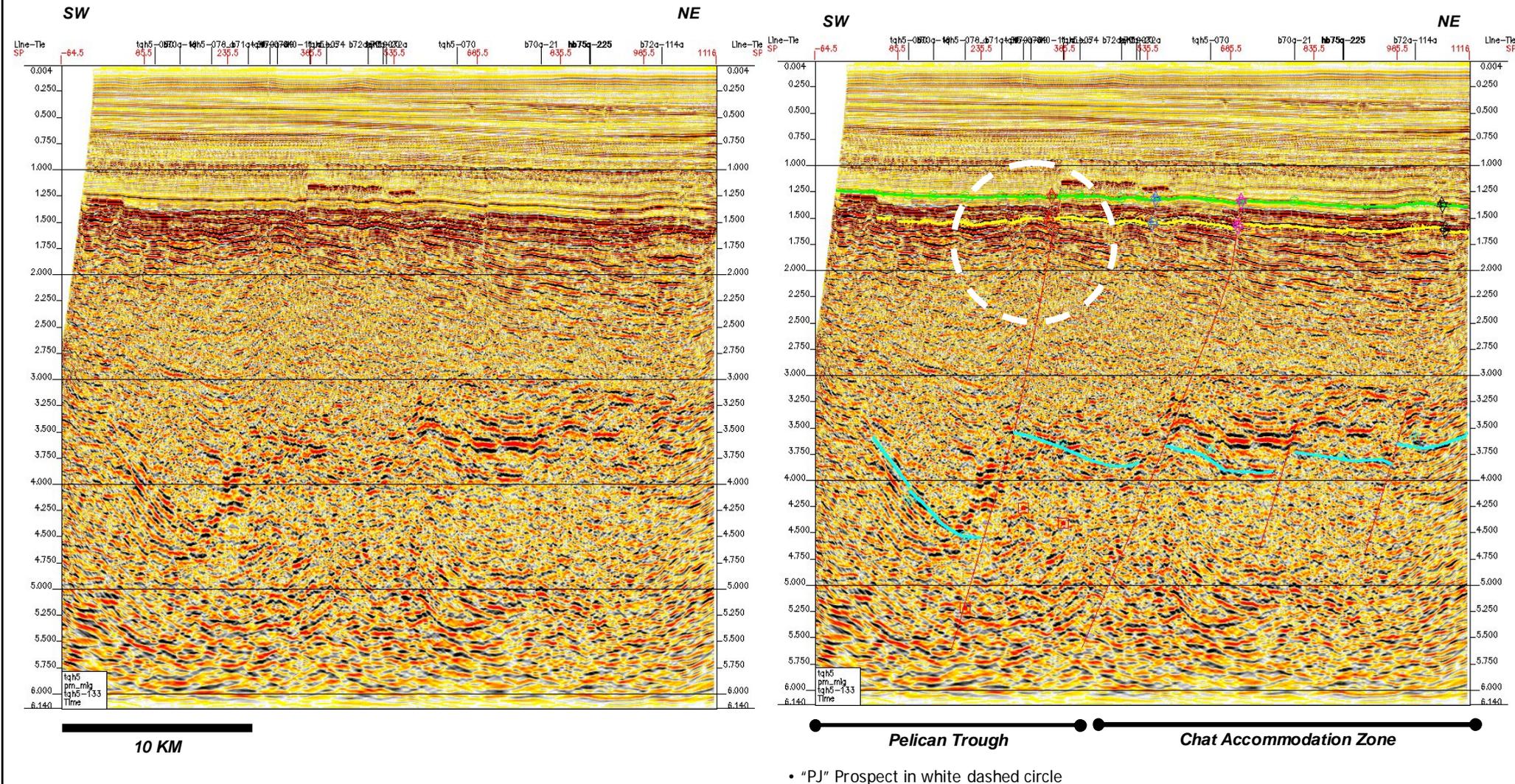
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# T39/P Seismic Basement Mapping

## TQH5-133 – Potential inversion structure nucleated over internal faulting in Pelican Trough



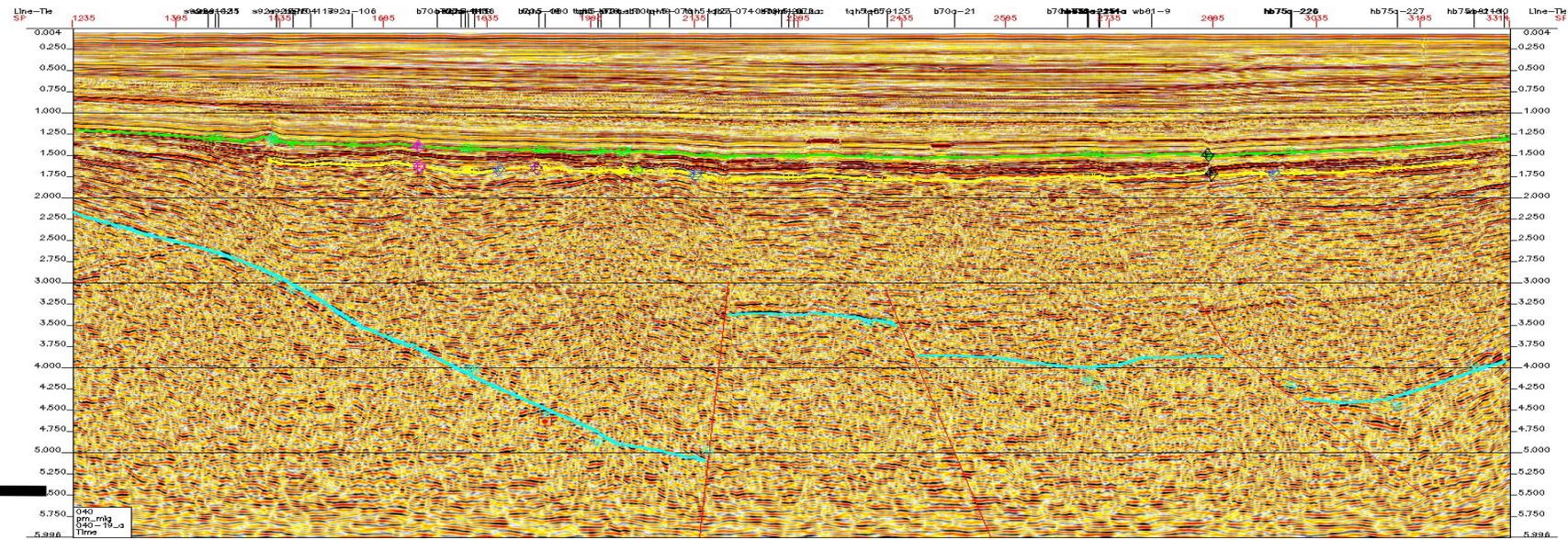
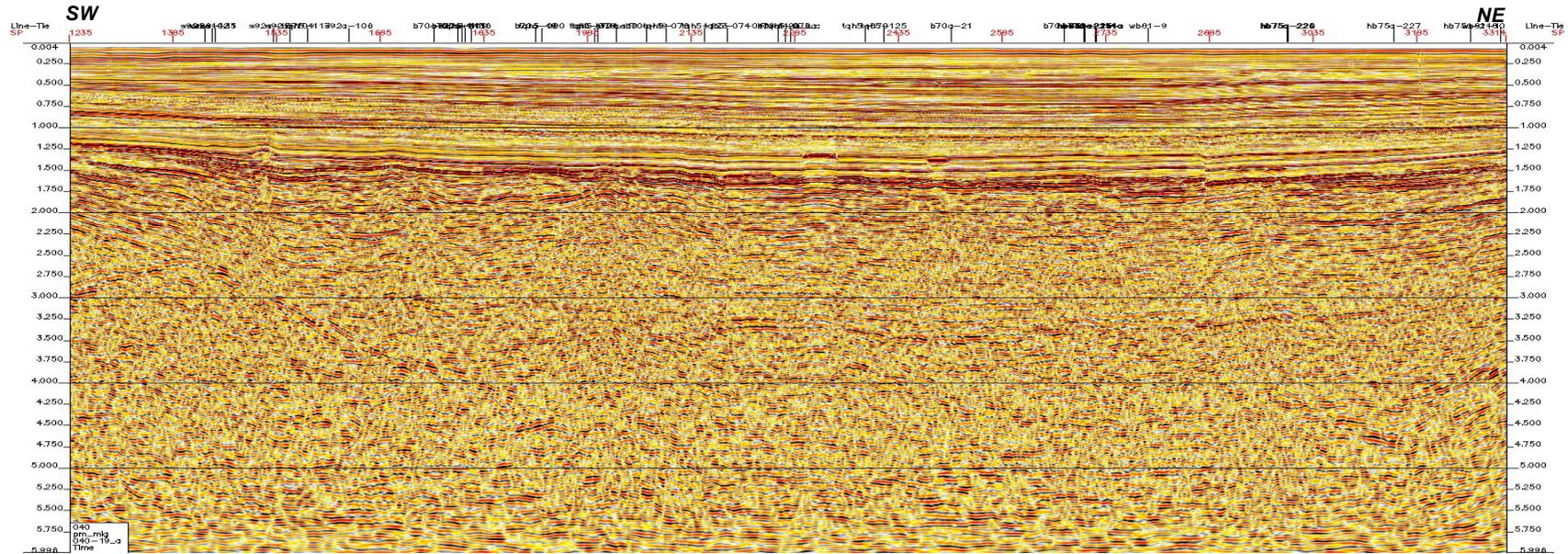
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# T39/P Seismic Basement Mapping

## 040-19A Regional view across Pelican and Dondu troughs



Pelican Trough

Dondu Trough



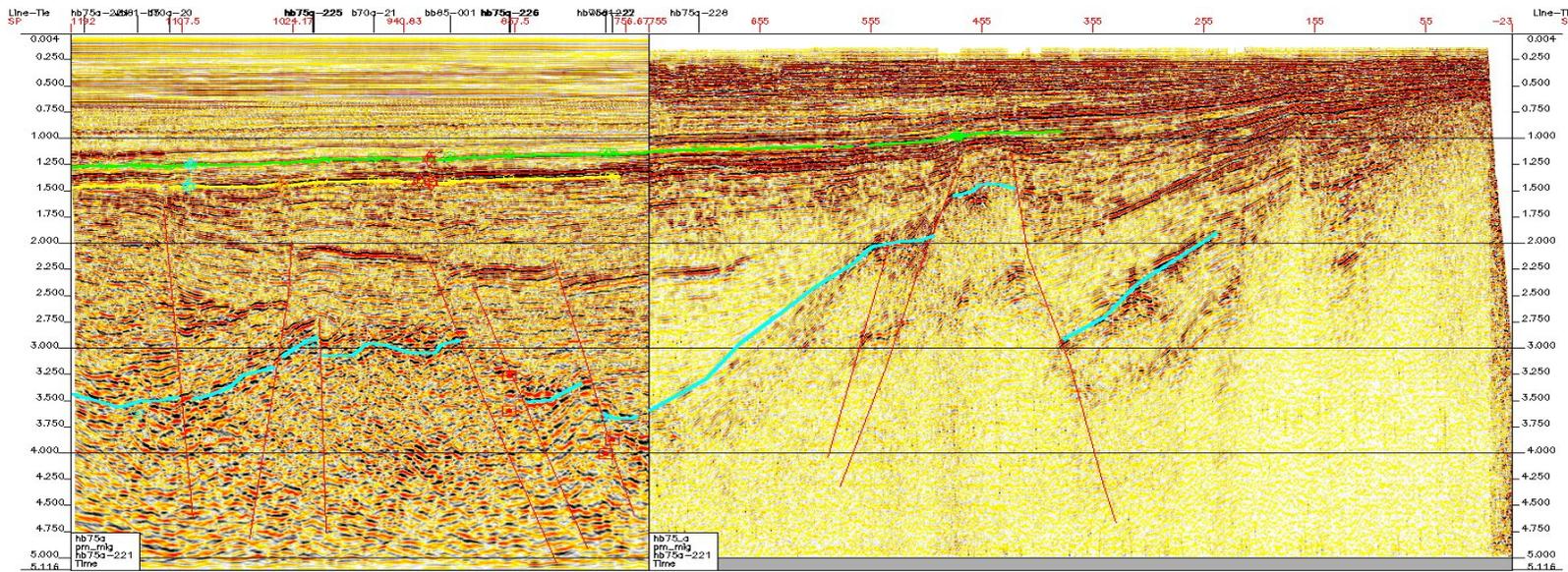
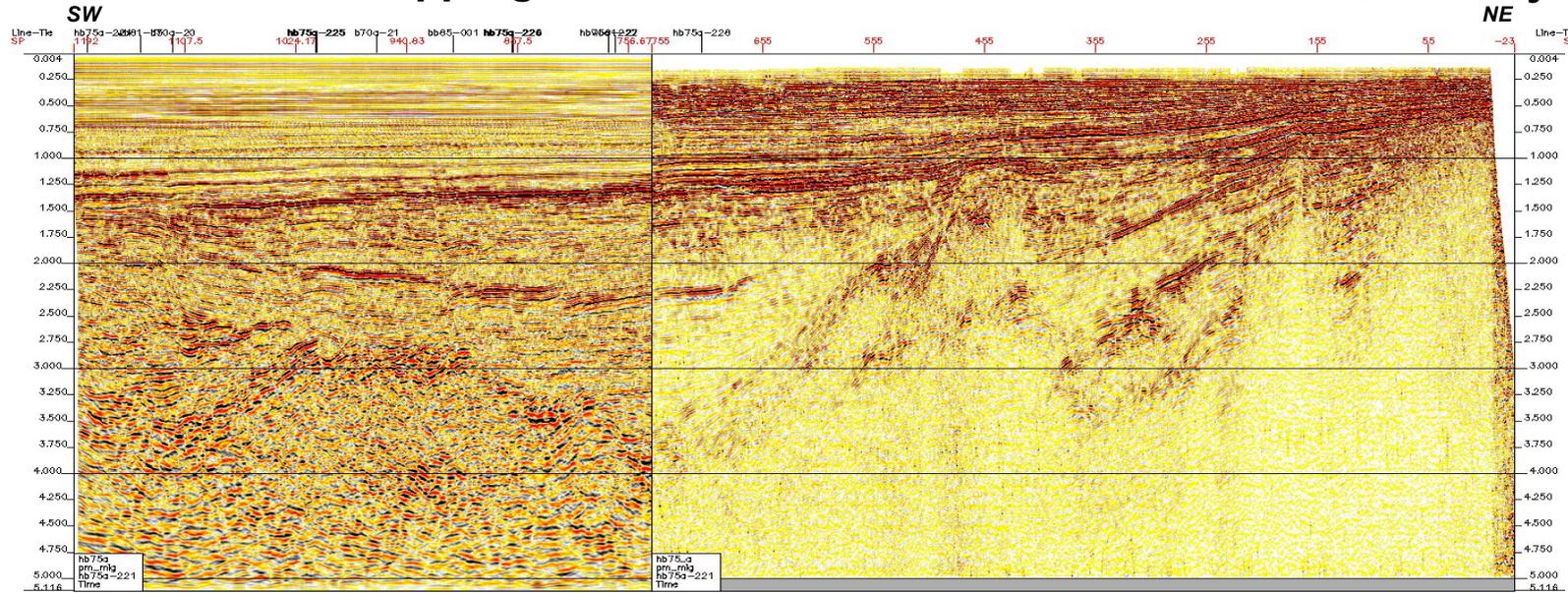
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# T39/P Seismic Basement Mapping

## HB75A-221 – East of Chat accom. zone, boundary faults dip to NE



Chat Accommodation Zone

Bark Trough

Durroon Sub-Basin

Boobyalla Trough

10 KM



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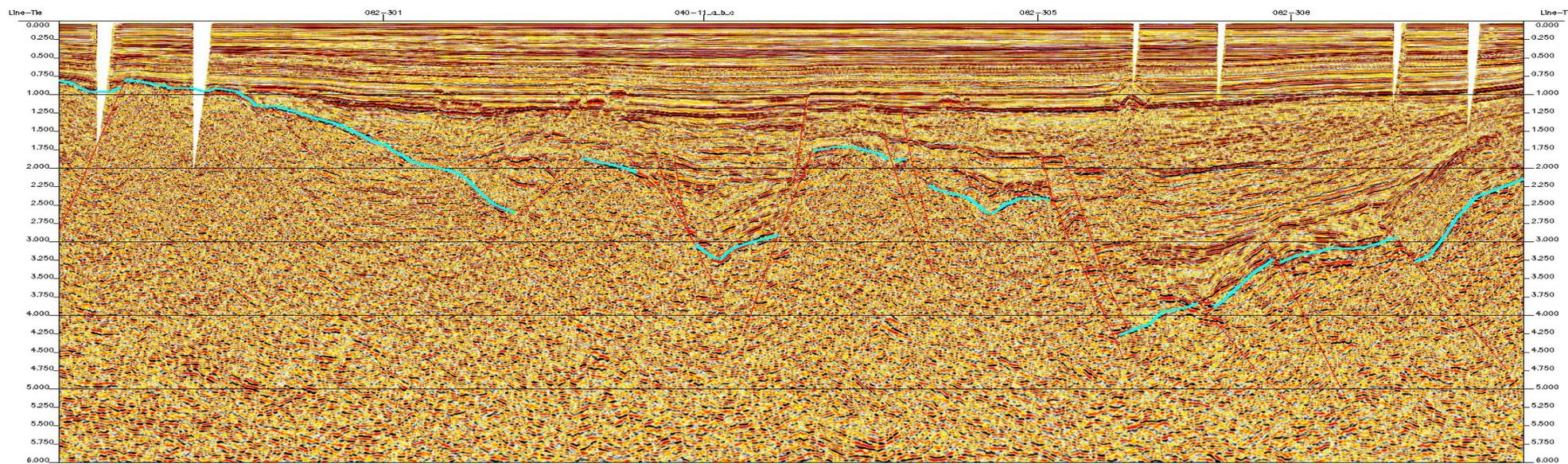
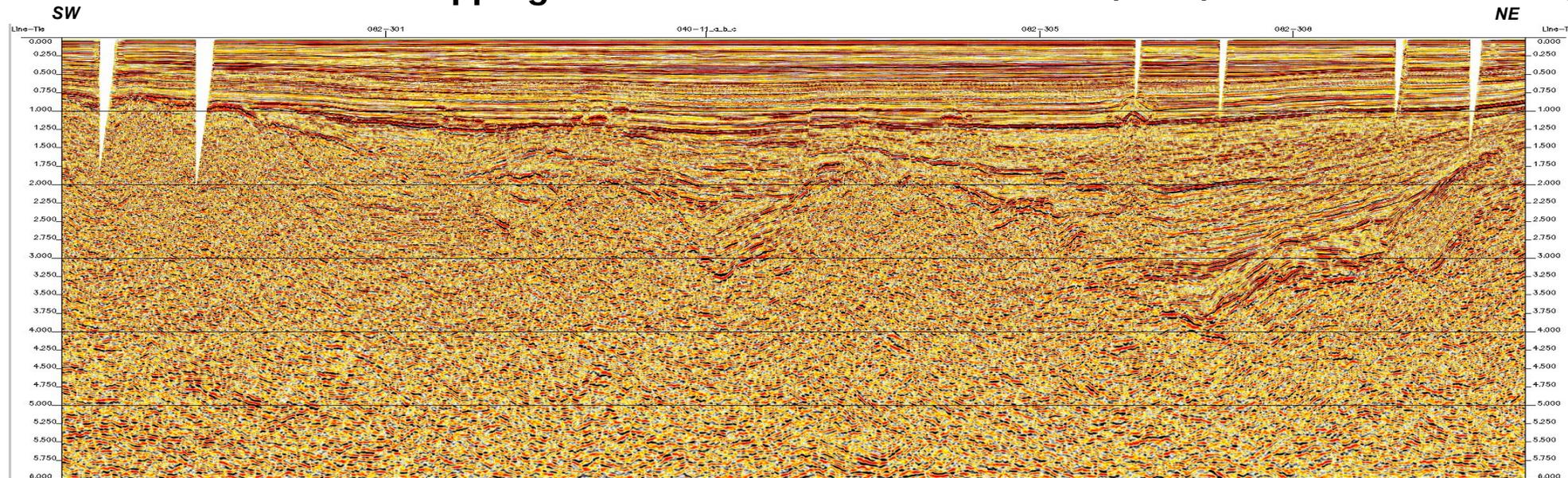
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# T39/P Seismic Basement Mapping

## 82-302 – Multiple depocentres in Pelican Trough



10 KM

Pelican Trough

Chat  
Accom Zone

Unnamed troughs & highs

Bark Trough



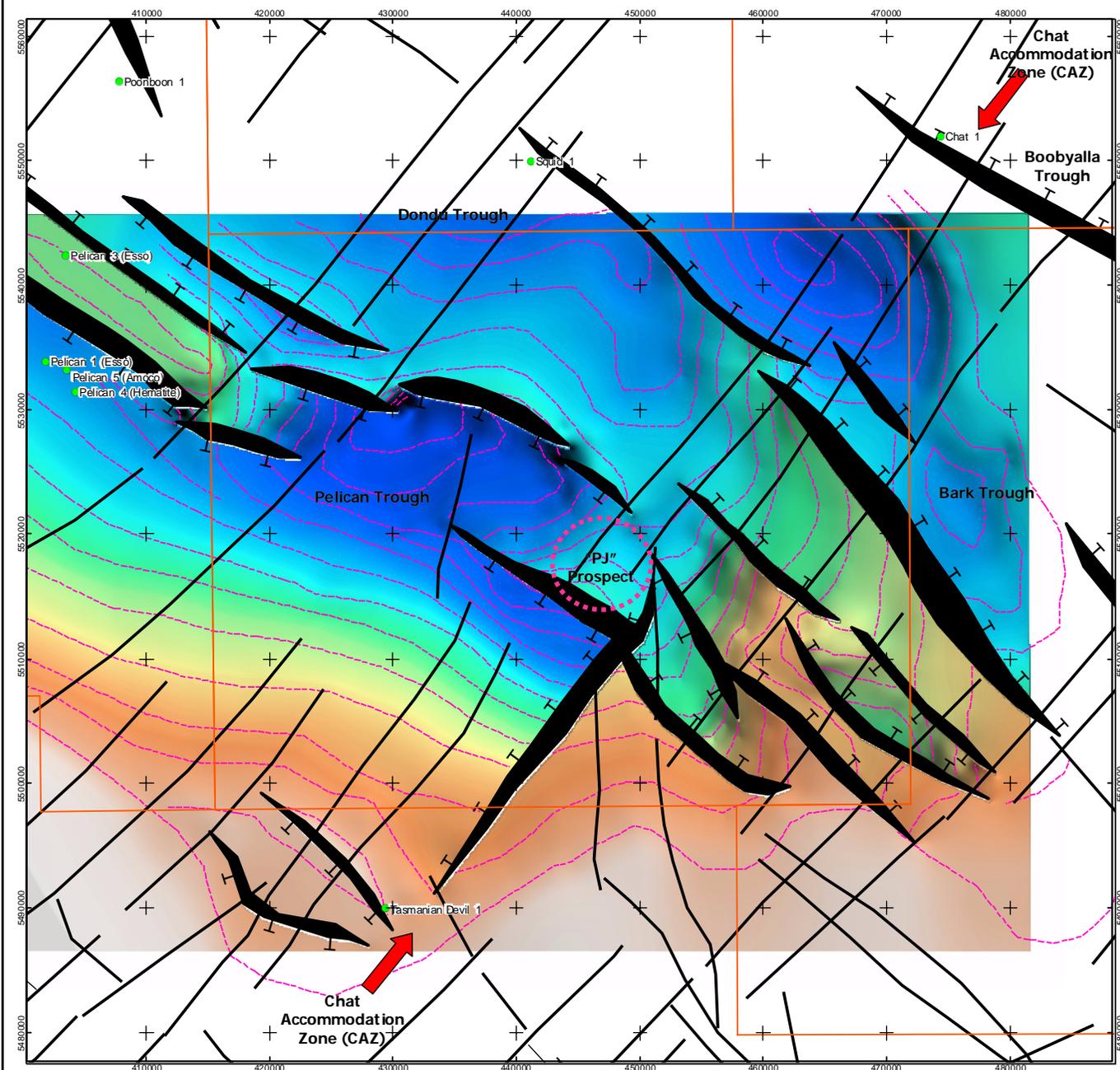
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# T39P SEEBASE™ + Structural Interpretation



• This map shows the Bass Basin T39/P SEEBASE™ + structural interpretation. The deep basin architecture in T39/P is complex, largely because of the complex array of basement structures that were reactivated to form the basin.

• Due to the nature of the datasets used to generate this interpretation, in reality the structural framework and basin architecture of T39/P are likely to be more complex than shown here. We recommend revising this interpretation when new data is available (e.g. 3D seismic).

• The geometry of the Bass Basin consists of a series of tilted, NW-trending basement fault blocks compartmentalized by NE-trending transfer/accommodation zones.

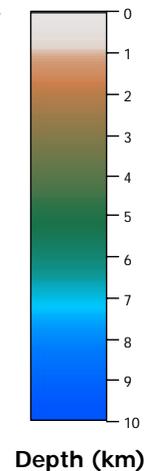
• Our interpretation shows the Pelican Trough as a NE-dipping half-graben bound to the NE by a series of major SW-dipping normal faults. The NE margin of the Pelican Trough is highly segmented and is defined by at least 6 major SW-dipping normal faults separated by transfer zones and relay ramps.

• The Pelican Trough reaches a maximum depth of ~10km in T39/P.

• The Pelican Trough terminates to the SE at the Chat Accommodation Zone (CAZ); a major NE-trending basement structural corridor that strongly compartmentalizes the Bass Basin. At the SE end of the Pelican Trough, the CAZ forms a steeply dipping sidewall fault. Further to the NE, the CAZ is defined by an array of steeply dipping basement faults that significantly influence basin architecture.

• To the E of the CAZ, the polarity of the half graben switches (e.g. Bark and Boobyalla Troughs dip to SW and are bound by NE-dipping normal faults).

• The area SW of the Bark Trough and E of the Pelican Trough is structurally complex and appears to contain a series of ~2-5km deep graben separated by basement highs.

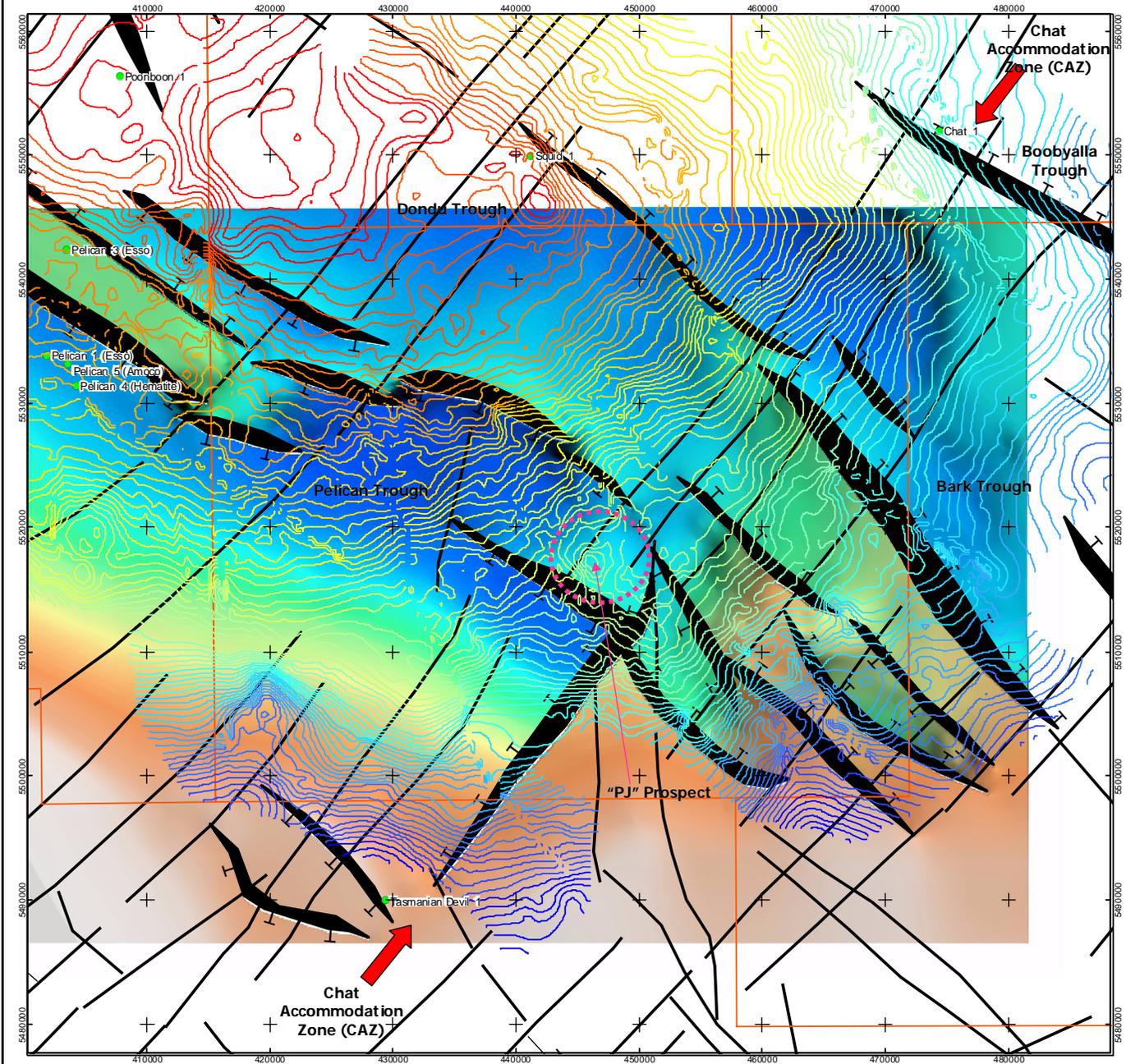


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# T39/P SEEBASE™ + Top Eastern View Group



- This map shows the Bass Basin T39/P SEEBASE™ + structural interpretation overlain by Benaris' Top Eastern View Group seismic interpretation (depth converted using equation on p19).

- Benaris' main "PJ" prospect formed via Mid-Late Miocene inversion of a major deep, NW-trending normal fault immediately to the SW of the prospect. The lateral offset between "PJ" and its controlling fault is due to the dip of the structure (see seismic examples on p23-24).

- The proximity of "PJ" prospect to the NE-trending Chat Accommodation Zone is significant since subtle reactivation of NE-trending basement structures is probably responsible for the along-strike closure of "PJ". Hence "PJ" prospect appears to occur in a structural "sweet spot".

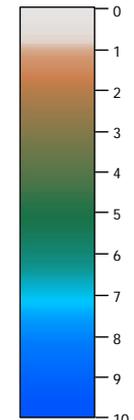
- Further similar "sweet spot" prospects may occur near the intersections of NW-trending inverted normal faults and NE-trending accommodation zones.

- A major NW-dipping relay ramp occurs to the NW of "PJ" prospect, as basement dips down into the deepest part of the Pelican Trough. This relay ramp may have been a migration pathway from any deeply-sourced hydrocarbons into "PJ".

Depth to top Eastern View Group (m)

- -2160 - -2060
- -2059 - -1940
- -1939 - -1860
- -1859 - -1780
- -1779 - -1680
- -1679 - -1560
- -1559 - -1460
- -1459 - -1360
- -1359 - -1260
- -1259 - -1160
- -1159 - -1060
- -1059 - -960
- -959 - -860
- -859 - -760
- -759 - -640

SEEBASE™ Depth (km)

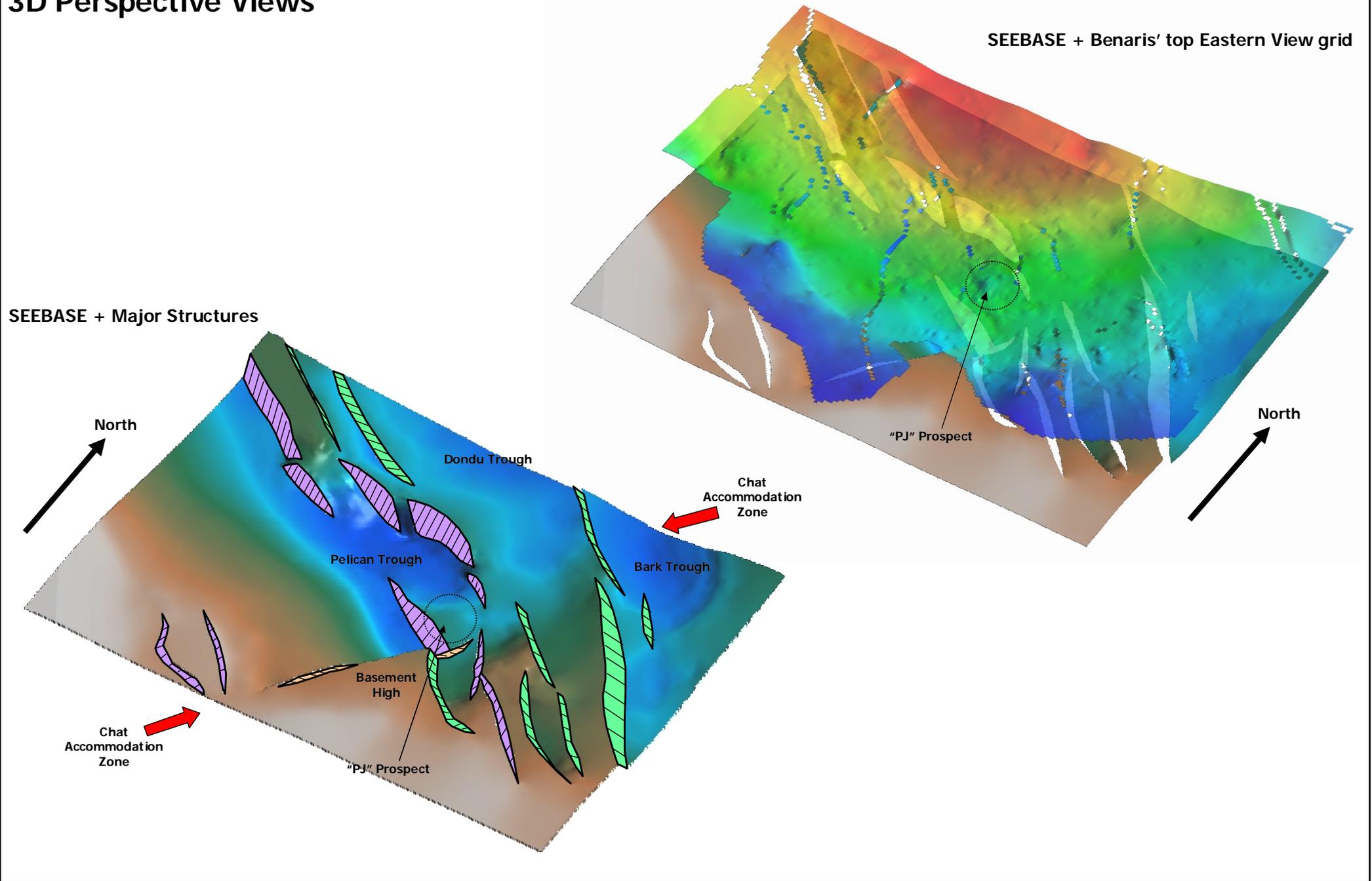


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# 3D Perspective Views



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## Conclusions

The Bass Basin T39/P SEEBASE™ study presents a refined view of the structural evolution and architecture of the southern Bass Basin. This map-view interpretation provides a consistent base on which to build a new geological understanding of the area. The results give Benaris a top-basement pick that is consistent with existing seismic and non-seismic data.

Key technical outcomes of the study include:

### Datasets and Calibration:

- Datasets compiled and processed for the Bass Basin SEEBASE™ Project (Teasdale et al, 2001) were used in this study, which builds upon the previous interpretation.
- The main additional data used for this study was the reprocessed 2D seismic database purchased by Benaris from Fugro.
- A GIS project including well data, surface geology, topography/bathymetry, infrastructure, magnetic images, seismic navigation data was constructed, and all interpretations were carried out in this environment in map-view.
- FrOG Tech's extensive knowledge base of the geology Southern Australia was used to interpret the area.

### Basement Geology:

- The basement terranes, composition and structure of the Bass Strait area have been interpreted. T39/P spans two basement terranes which underwent complex Neoproterozoic-Paleozoic evolution.
- The location and geometry of basement structures was interpreted, with a view to understanding how pre-existing basement structures have influenced later basin evolution.

### Basin Structure and Evolution

- Three key structural events are important in the Bass Basin:
  - (i) Early Cretaceous NE-SW rifting
  - (ii) Late Cretaceous "Tasman Sea" ENE-WSW rifting
  - (iii) Subtle Mid-Late Miocene inversion
- Two sets of major basement structures have significantly influenced Mesozoic-Cenozoic basin evolution:
  - (i) NW-trending Paleozoic structures/terrace boundary have localized Cretaceous rifting and have been reactivated as normal and oblique normal faults. These structures bound the main depocentres in the Bass Basin
  - (ii) NE-trending Neoproterozoic structures have been reactivated as transfer/accommodation zones during both Cretaceous rift events. These structures compartmentalize the rift structures in the Bass Basin.
- In this study we have undertaken a detailed interpretation of the location and geometry of these rift structures in T39/P.

### Basement Architecture and Depth - SEEBASE™

- A SEEBASE™\* model of T39/P defines basement topography and basin architecture. SEEBASE™ was constructed using a combination of seismic top-basement interpretation, magnetic depth modeling, and structural interpretation. SEEBASE™ can also be used to map play element distribution, migration pathways and trap type/distribution.
- The T39/P SEEBASE™ and structural interpretation shows that:
  - The Pelican Trough forms a NE-dipping half-graben bound to the NE by a series of major SW-dipping normal faults separated by transfer zones and relay ramps.
  - The Pelican Trough terminates to the SE at the Chat Accommodation Zone; a major NE-trending basement structural corridor that strongly compartmentalizes the Bass Basin.
  - To the E of the Chat Accommodation Zone, the polarity of the half graben switches and the troughs of the Durroon Sub-basin dip to the SW and are bound by NE-dipping normal faults.
  - The area SW of the Bark Trough and E of the Pelican Trough is structurally complex and appears to contain a series of ~2-5km deep graben separated by basement highs.

### Implications for Prospectivity

- Mid-Late Miocene inversion of deep Cretaceous normal faults is responsible for closures at Eastern View level.
- Benaris' main "PJ" prospect formed via Miocene inversion of an Early Cretaceous normal fault.
- The "PJ" prospect lies within the Chat Accommodation Zone, which is probably responsible for the along-strike closure of "PJ". Hence "PJ" prospect appears to occur in a structural "sweet spot" at the intersection of two major structural corridors.
- Other prospects such as Pelican also formed during Miocene inversion of deep Cretaceous normal faults, however the absence of NE-trending "cross" structures may have prevented the development of along-strike closures at Eastern View reservoir level.
- Further similar "sweet spot" prospects may occur near the intersections of NW-trending inverted normal faults and NE-trending accommodation zones.
- Top-basement relay ramps near "PJ" may have acted as migration pathways from any deeply-sourced hydrocarbons in the Pelican Trough into "PJ".

### GIS:

- All interpretive layers are captured digitally in ArcGIS format.

\*SEEBASE™ = Structurally Enhanced view of Economic Basement



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