

The Source of Oil and Gas Accumulations in the Browse Basin, North West Shelf of Australia: A Geochemical Assessment*

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Abstract

The Browse Basin located offshore on Australia's North West Shelf hosts considerable, but as yet undeveloped, petroleum resources with 36 Tcf EUR (Estimated Ultimate Recovery) of gas and 1148 MMbbl of condensate. It is poised to become Australia's next major conventional liquefied natural gas (LNG) province with the Ichthys, Prelude and Concerto fields expected to be in production by the end of 2016. Significant gas accumulations are also found along, and to the northeast of, the Brecknock-Scott Reef Trend (Calliance, Brecknock, Torosa and Poseidon) and in the Heywood Graben (Crux). Despite the economic importance of these fields and the extensive ongoing exploration activity, the origin of hydrocarbons remains ambiguous and a thorough geochemical evaluation of reservoir fluids and source rocks was carried out to redefine the petroleum systems of the Browse Basin. Geochemical data reveal that the gas-prone source rocks occurring throughout the Lower to Middle Jurassic Plover Formation have pervasively charged reservoirs of the Browse Basin at numerous stratigraphic levels.

On the other hand, oil-prone source rocks within the Upper Jurassic Lower Vulcan and Lower Cretaceous Echuca Shoals formations appear to be charge limited. The fluvio-deltaic sediments of the Plover Formation are the primary source for the dry gas found in the Plover reservoirs of the Brecknock-Scott Reef Trend and Ichthys fields. The Plover source rocks have also contributed to the wet gas accumulations reservoired within the Upper Jurassic Brewster Member of the Ichthys and Prelude/Concerto fields with additional inputs from the Lower Vulcan Formation. Gases from the Crux Field in the Heywood Graben are isotopically more enriched in ¹³C than any gases generated from the Caswell Sub-basin depocenter, suggesting derivation from coal-rich facies within thick Jurassic syn-rift sediments. The few sub-economic oil discoveries made in the Browse Basin are confined to the central Caswell Sub-basin (Caswell) and to the Yampi Shelf (Cornea, Gwydion and surrounds) where oil, together with some gas, is found in Cretaceous reservoirs. Molecular and carbon isotopic data show that the oil, and the

gas to some extent, is derived from marine organic matter within the Echuca Shoals Formation. However, accumulations on the Yampi Shelf also contain gases sourced from Plover source rocks, emphasising the migration of multiple hydrocarbon charges towards the basin margins.

References Cited

Blevin, J.E., C.J. Boreham, R.E. Summons, H.I.M. Struckmeyer, and T.S. Loutit, 1998, An effective Lower Cretaceous petroleum system on the North West Shelf: Evidence from the Browse Basin, *in* P.G. Purcell, ed., The Sedimentary Basins of Western Australia 2: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, WA, p. 397-420.

Boreham, C.J., and D.E. Edwards, 2008, Abundance and carbon isotopic composition of neopentane in Australian natural gases: Organic geochemistry, v. 39/5, p. 550-566.

Edwards, D.S., C.J. Boreham, J.E. Zumberge, J.M. Hope, J.M. Kennard, and R.E. Summons, 2006, Hydrocarbon families of the Australian North West Shelf: A regional synthesis of the bulk, molecular and isotopic composition of oils and gases: AAPG International Conference and Exhibition, 5-8 November, Perth, Australia.

http://www.searchanddiscovery.com/abstracts/pdf/2006/intl_perth/abstracts/ndx_edwards.pdf?q=%2BauthorStrip%3Aedwards+%2ByearSort%3A%5B2006+TO+2006%5D



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Geoscience Australia, Energy Systems Group, Resources Division
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Consider the Source

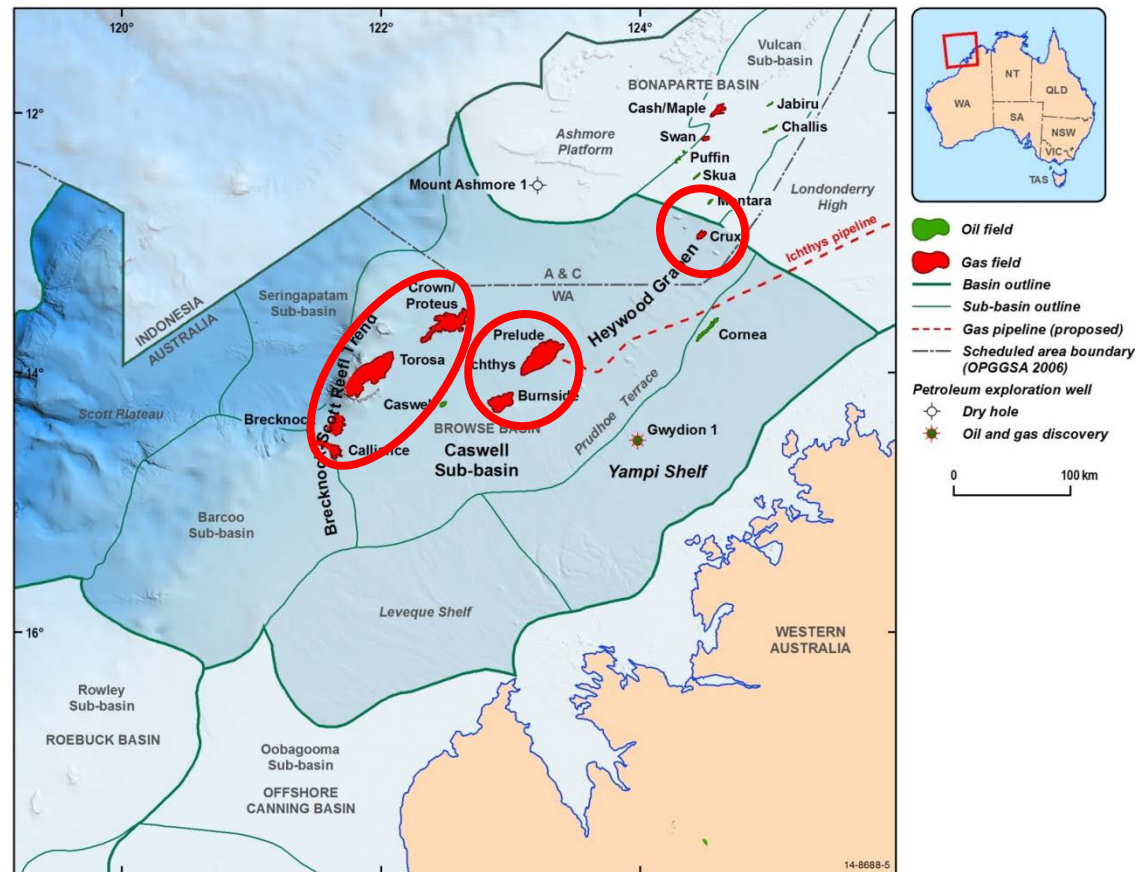
APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

AAPG/SEG ICE,
Melbourne 13–16 September 2015



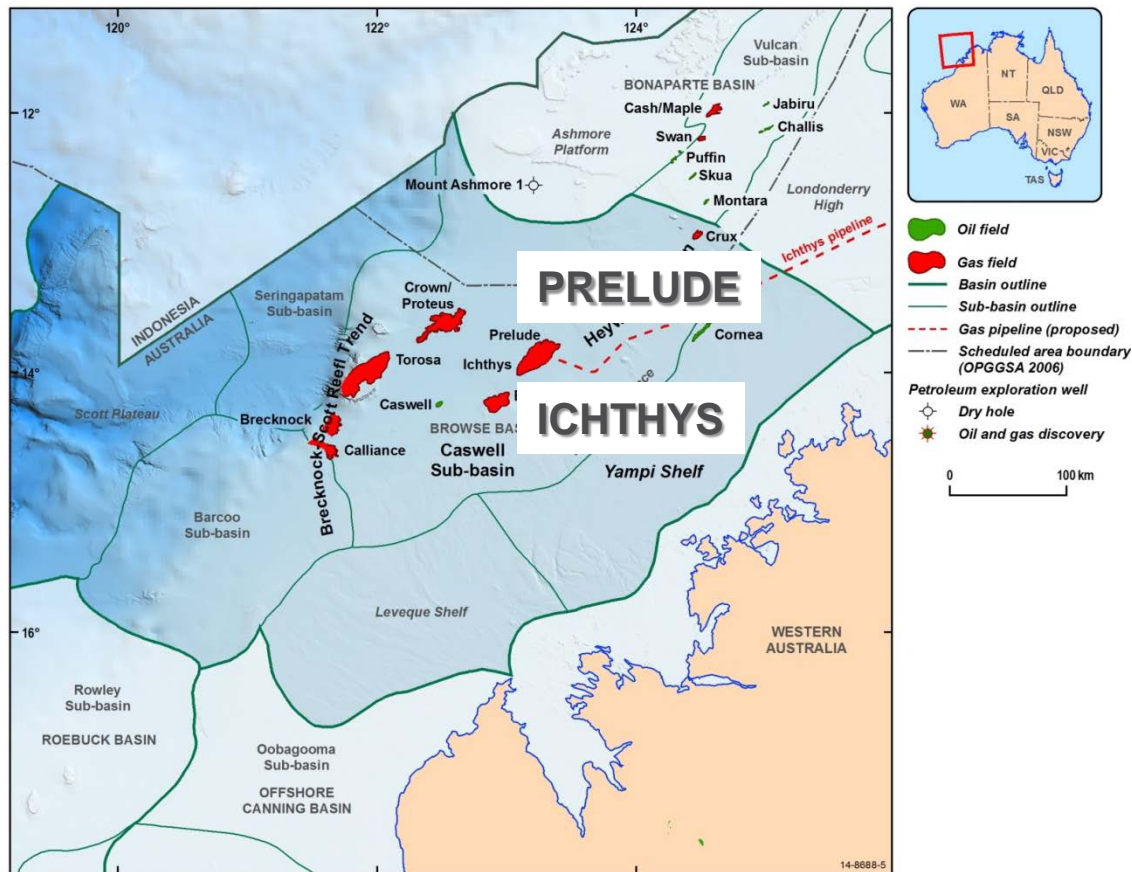
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Browse Basin oil and gas accumulations



➤ Gas accumulations in Calliance/Brecknock/Torosa, Ichthys/Prelude and Crux

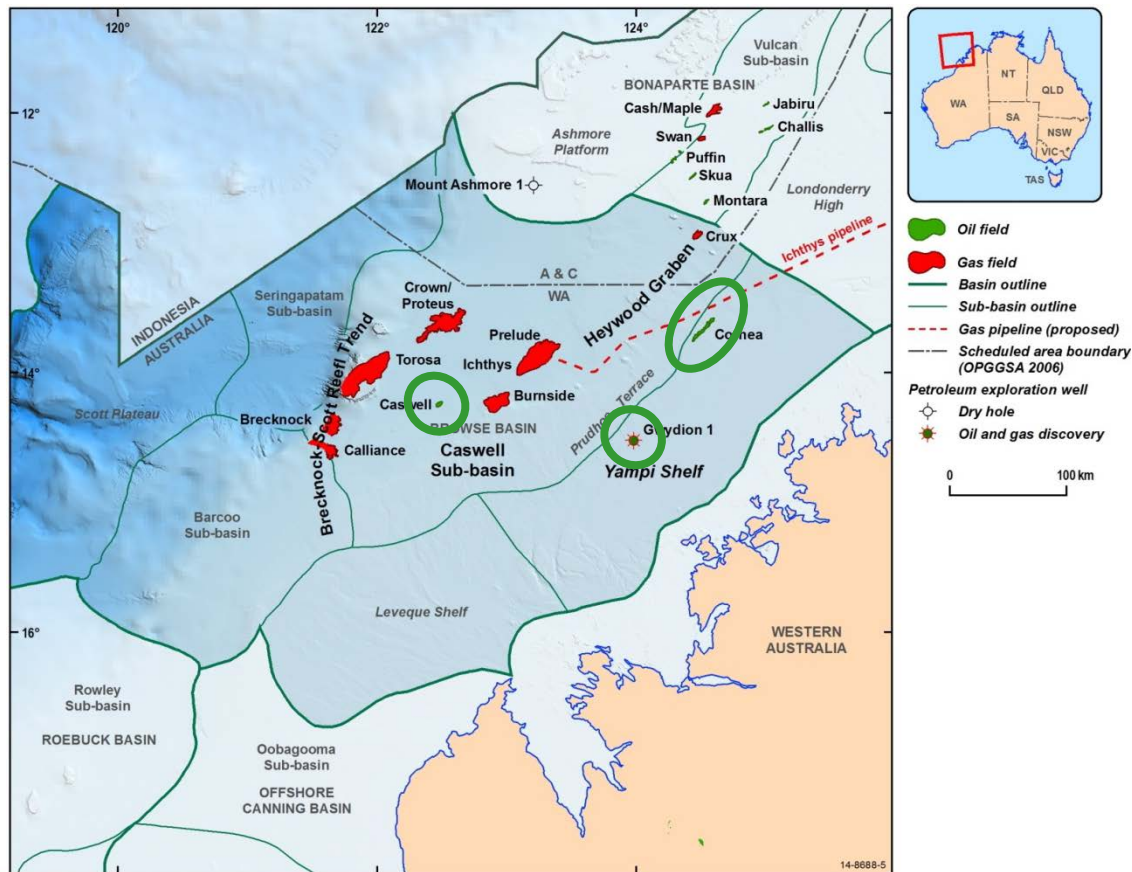
Browse Basin oil and gas accumulations



➤ Gas accumulations in Calliance/Brecknock/Torosa, Ichthys/Prelude and Crux

➤ Ichthys/Prelude: on track to deliver first LNG volumes in 2016

Browse Basin oil and gas accumulations



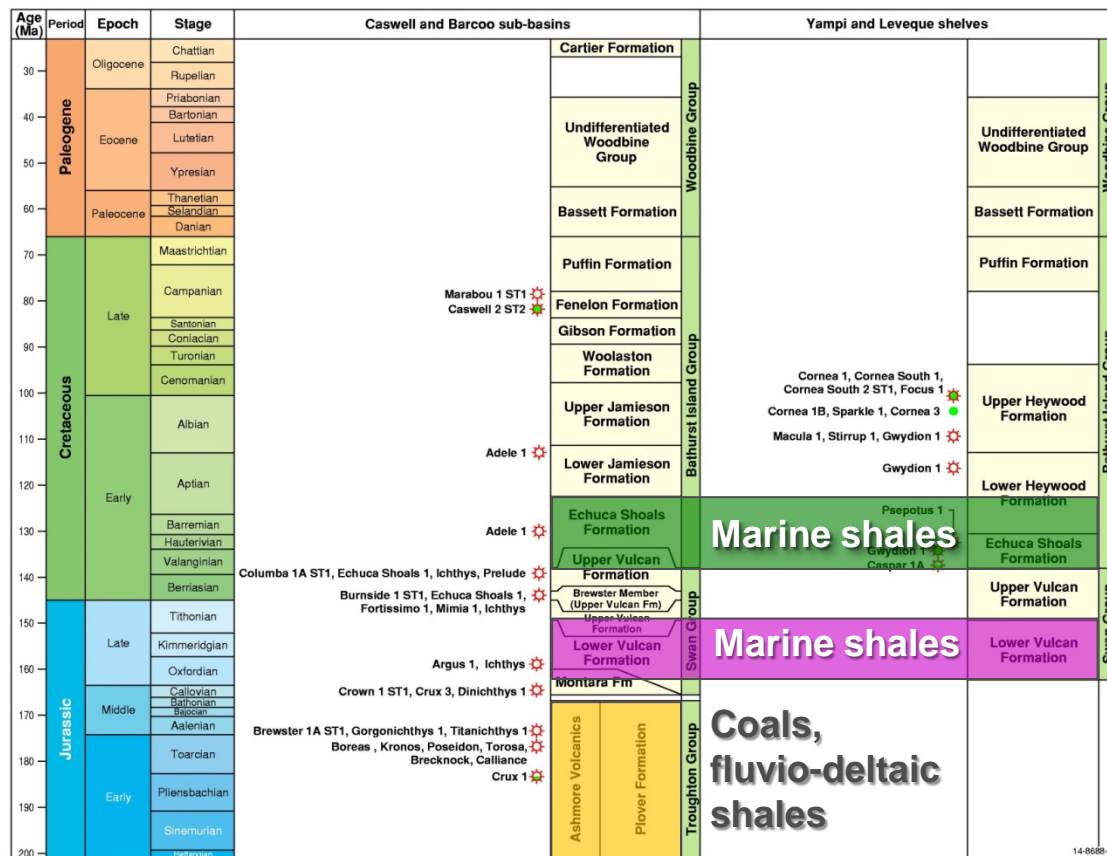
➤ Gas accumulations in Calliance/Brecknock/Torosa, Ichthys/Prelude and Crux

➤ Ichthys/Prelude: on track to deliver first LNG volumes in 2016

➤ Oil accumulations:

- Cornea/Gwydion 1
- Caswell 1 and 2

Browse Basin Stratigraphy: Source Rocks



**Echuca Shoals Fm.:
Source of oils in the
Browse Basin**

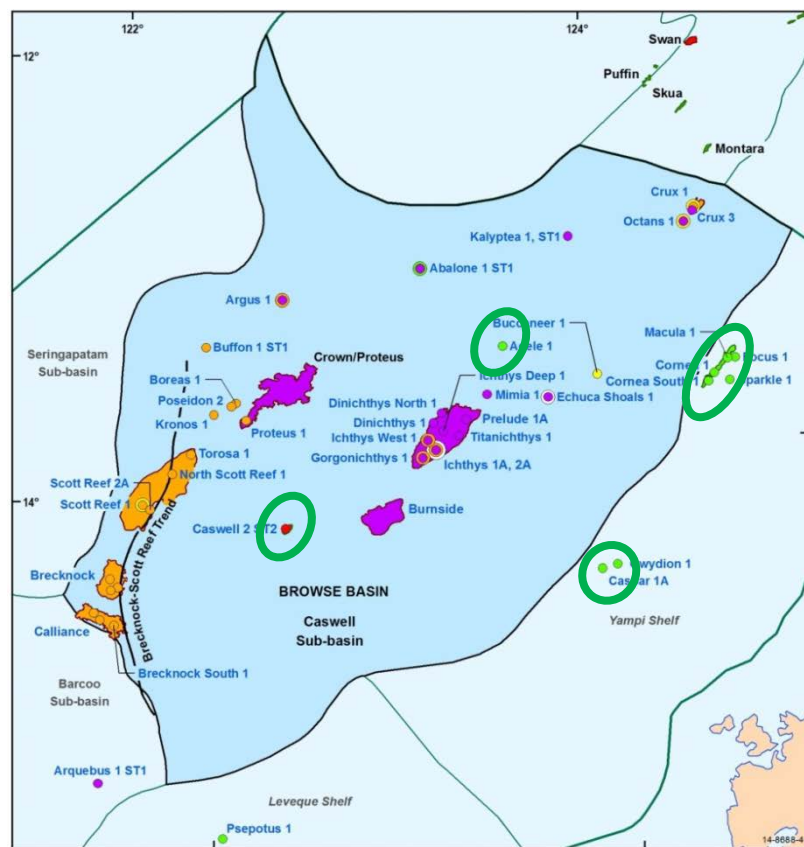
*Blevin et al., 1998
BBHR study*

Echuca Shoals

Lower Vulcan

Plover

Accumulations by Reservoir: Post-Berriasian Cretaceous

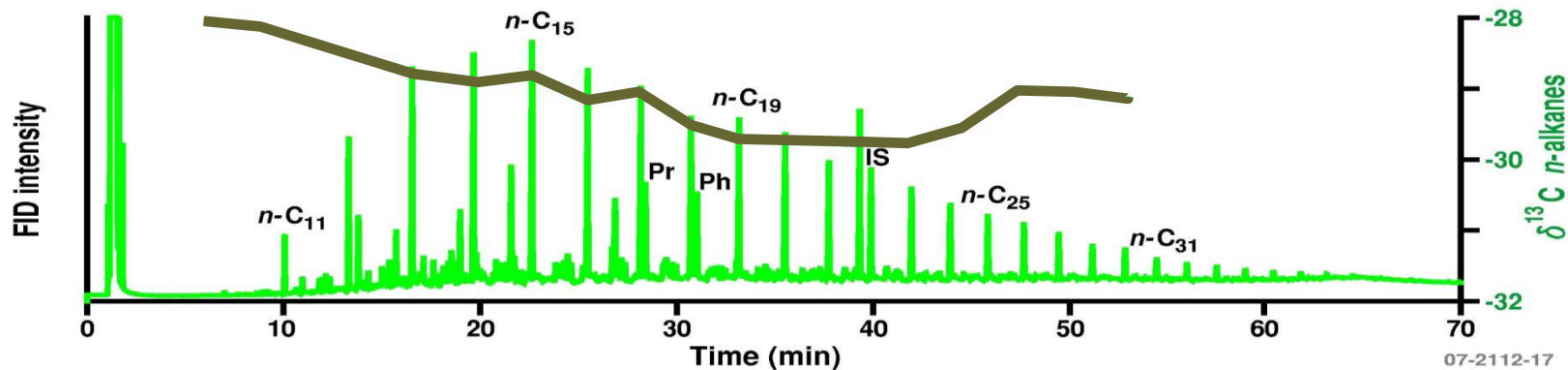
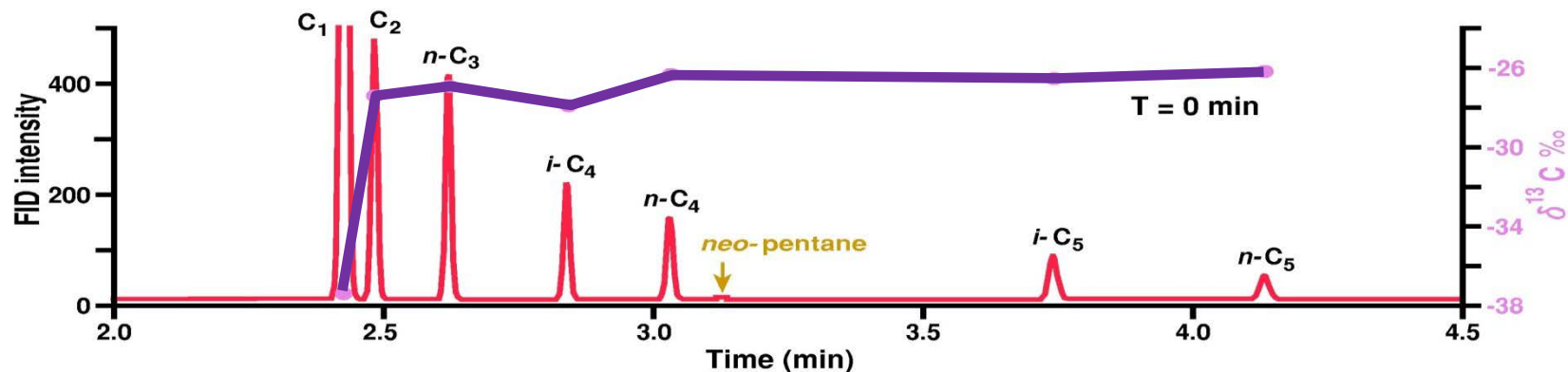


Age (Ma)	Period	Epoch	Stage	
30 40 50 60	Paleogene	Oligocene	Chattian	
			Rupelian	
			Priabonian	
		Eocene	Barionian	
			Lutetian	
			Ypresian	
		Paleocene	Thanetian	
			Selandian	
			Danian	
70 80 90 100 110 120 130 140 150 160 170 180 190 200	Cretaceous	Late	Maastrichtian	
			Campanian	
			Santonian	
			Coniacian	
			Turonian	
			Cenomanian	
		Early	Albian	
			Aptian	
			Barremian	
			Hauterivian	
			Valanginian	
			Berriasian	
			Late	Tithonian
				Kimmeridgian
				Oxfordian
				Callovian
Middle	Bathonian			
	Albian			
	Aalenian			
	Early	Toarcian		
		Pliensbachian		
		Sinemurian		

Post-Berriasian Cretaceous Reservoirs

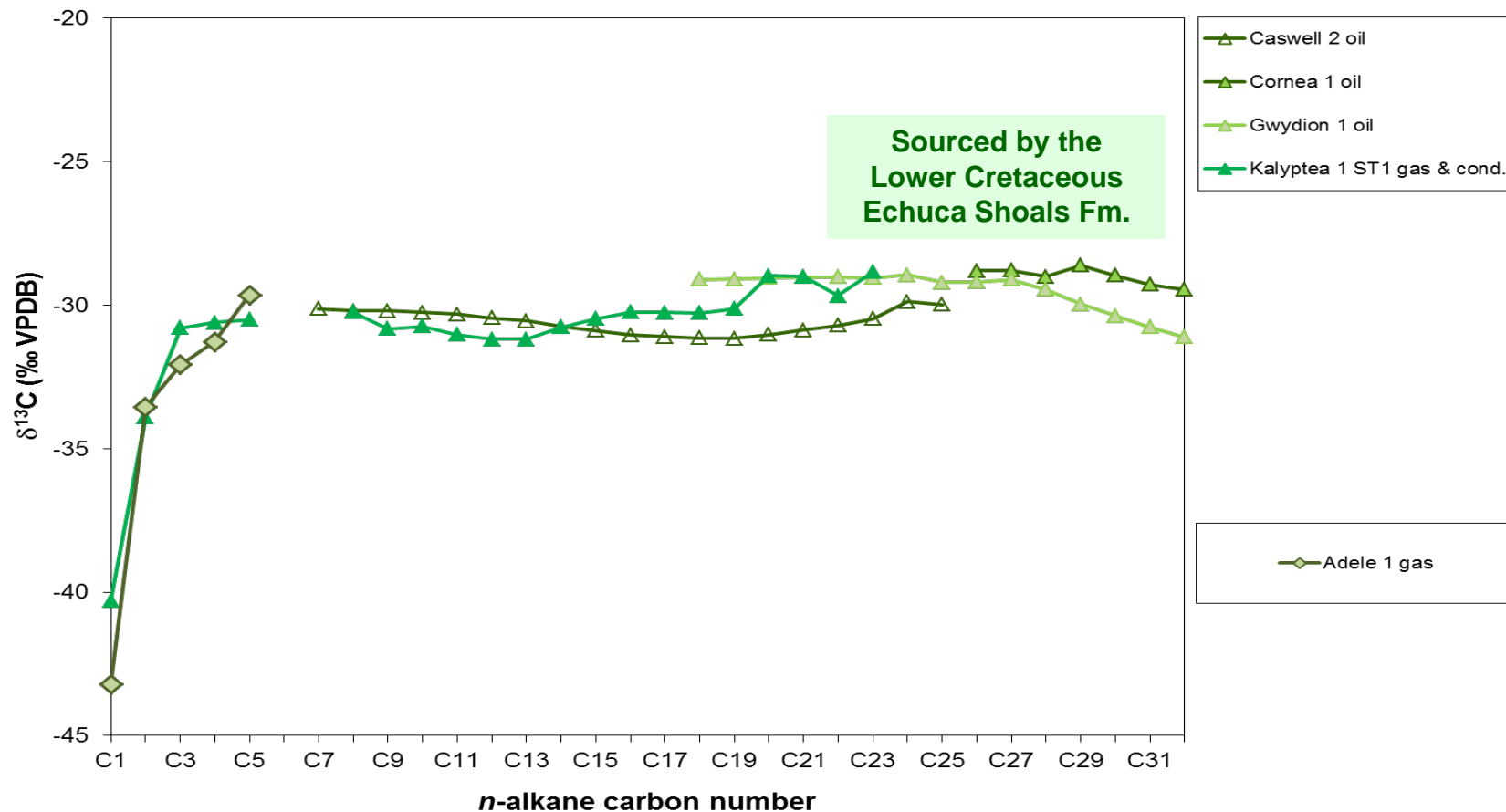
Caswell and Barcoo sub-basins			Yampi and Leveque shelves		
Caswell 2 ST2	Adele 1	Cartier Formation	Woodbine Group	Woodbine Group	Woodbine Group
		Undifferentiated Woodbine Group			
		Bassett Formation			
		Puffin Formation			
		Fenelon Formation			
		Gibson Formation			
		Woolaston Formation			
		Upper Jamieson Formation			
		Lower Jamieson Formation			
		Echuca Shoals Formation			
Columba 1A ST1, Echuca Shoals 1, Ichthys, Prelude	Adele 1	Upper Vulcan Formation	Bathurst Island Group	Bathurst Island Group	Bathurst Island Group
		Brewster Member (Upper Vulcan Fm)			
		Upper Vulcan Formation			
		Lower Vulcan Formation			
		Montara Fm			
		Ashmore Volcanics			
		Plover Formation			
		Troughland Group			
Burnside 1 ST1, Echuca Shoals 1, Fortissimo 1, Mimia 1, Ichthys	Adele 1	Upper Heywood Formation	Bathurst Island Group	Bathurst Island Group	Bathurst Island Group
		Lower Heywood Formation			
		Echuca Shoals Formation			
		Upper Vulcan Formation			
		Lower Vulcan Formation			
		Montara Fm			
		Ashmore Volcanics			
		Plover Formation			
		Troughland Group			
Argus 1, Ichthys	Adele 1	Upper Heywood Formation	Bathurst Island Group	Bathurst Island Group	Bathurst Island Group
		Lower Heywood Formation			
		Echuca Shoals Formation			
		Upper Vulcan Formation			
		Lower Vulcan Formation			
		Montara Fm			
		Ashmore Volcanics			
		Plover Formation			
		Troughland Group			
Crown 1 ST1, Crux 3, Dinichthys 1	Adele 1	Upper Heywood Formation	Bathurst Island Group	Bathurst Island Group	Bathurst Island Group
		Lower Heywood Formation			
		Echuca Shoals Formation			
		Upper Vulcan Formation			
		Lower Vulcan Formation			
		Montara Fm			
		Ashmore Volcanics			
		Plover Formation			
		Troughland Group			
Brewster 1A ST1, Gorgonichthys 1, Titanichthys 1, Boreas, Kronos, Poseidon, Torosa, Brecknock, Calliance, Crux 1	Adele 1	Upper Heywood Formation	Bathurst Island Group	Bathurst Island Group	Bathurst Island Group
		Lower Heywood Formation			
		Echuca Shoals Formation			
		Upper Vulcan Formation			
		Lower Vulcan Formation			
		Montara Fm			
		Ashmore Volcanics			
		Plover Formation			
		Troughland Group			

Compound-specific Isotopes

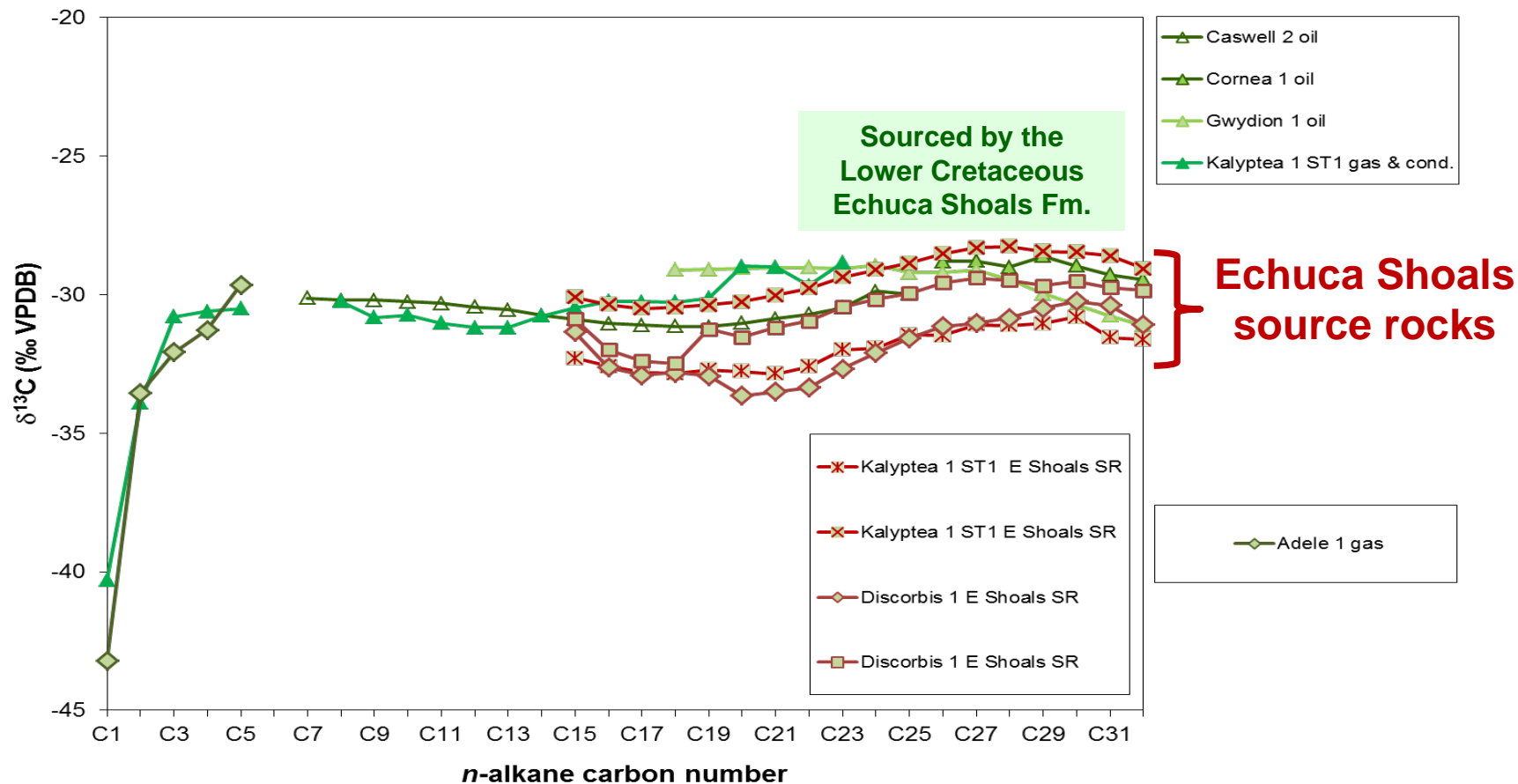


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Browse Basin Gas & Oil/Condensate Families

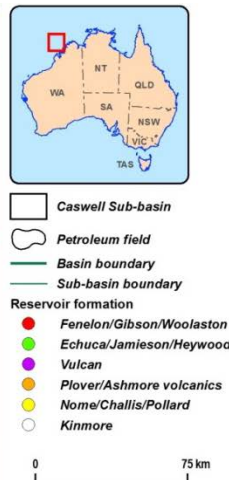
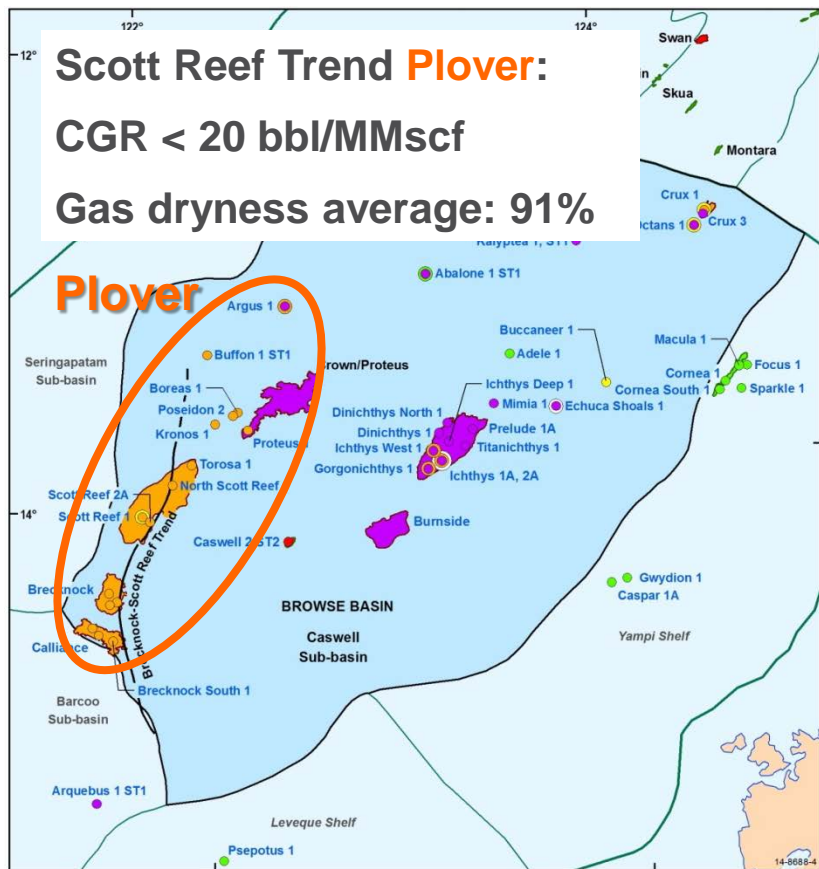


Browse Basin Gas & Oil/Condensate Families



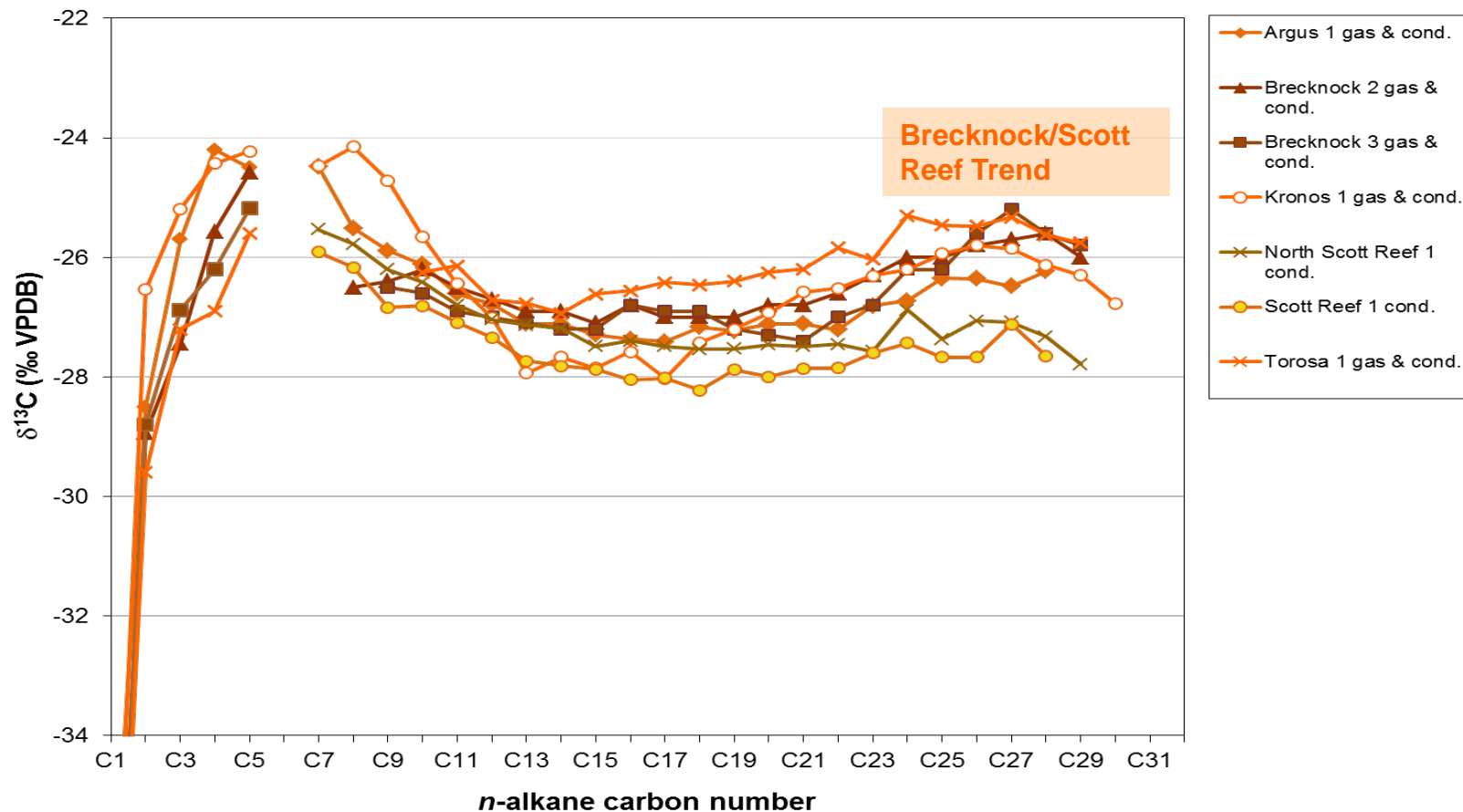
Gas accumulations: Brecknock/Scott Reef Trend

Scott Reef Trend **Plover**:
CGR < 20 bbl/MMscf
Gas dryness average: 91%

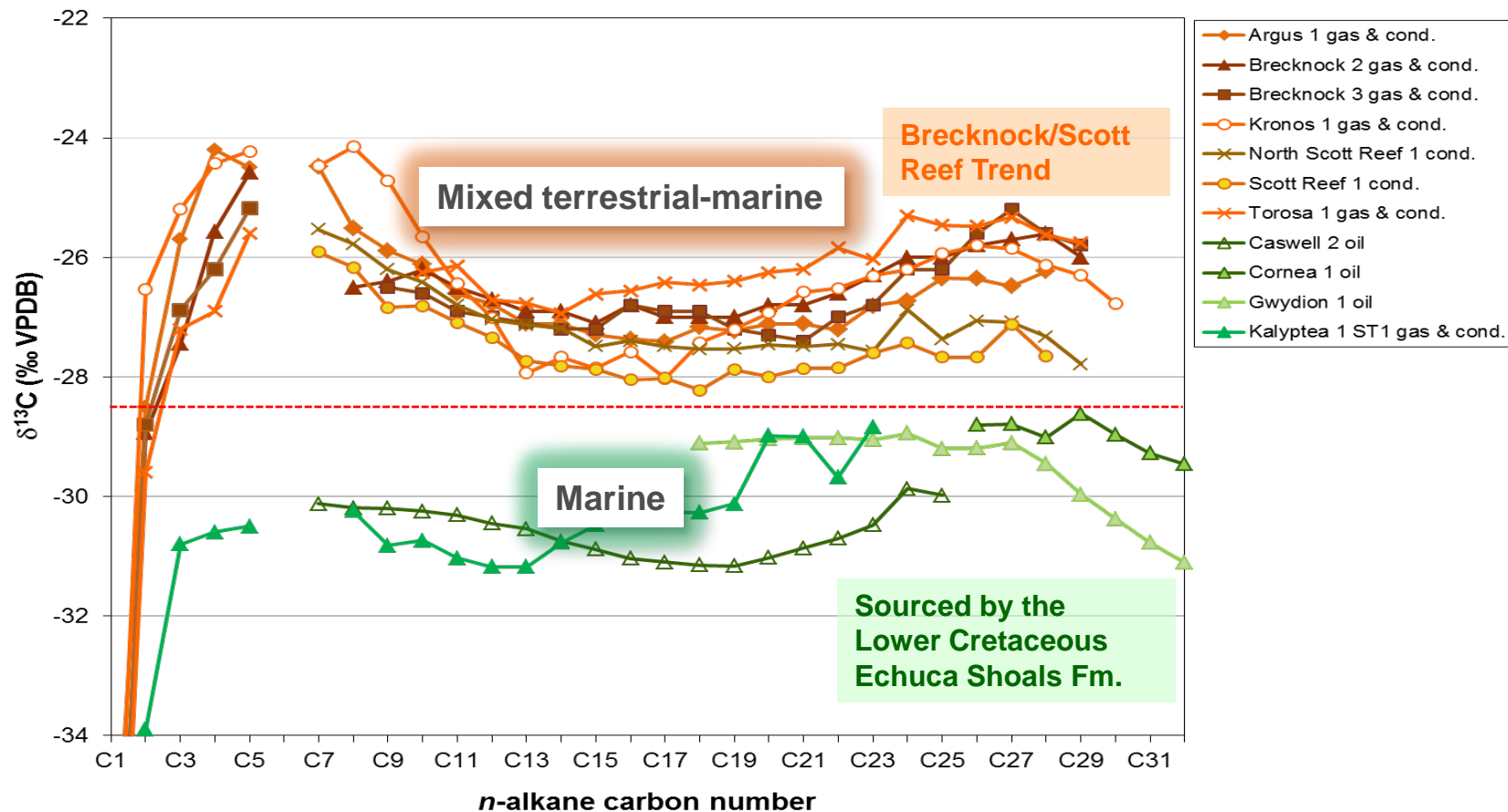


Age (Ma)	Period	Epoch	Stage	Caswell and Barcoo sub-basins																																						
30	Paleogene	Oligocene	Chattian	Cretaceous	Maastrichtian	Late	Early	Albian	Aptian	Barremian	Hauterivian	Valanginian	Berriasian	Tithonian	Kimmeridgian	Oxfordian	Callovian	Bathonian	Bacoon	Aalenian	Toarcian	Pliensbachian	Sinemurian	Hettangian	Cartier Formation	Undifferentiated Woodbine Group	Bassett Formation	Puffin Formation	Fenelon Formation	Gibson Formation	Woolaston Formation	Upper Jamieson Formation	Lower Jamieson Formation	Echuca Shoals Formation	Upper Vulcan Formation	Brewster Member (Upper Vulcan Fm)	Upper Vulcan Formation	Lower Vulcan Formation	Montara Fm	Ashmore Volcanics	Plover Formation	Troughout Group
			Rupelian																																							
			Priabonian																																							
			Bartonian																																							
			Lutetian																																							
		Eocene	Ypresian																																							
			Thanetian																																							
			Selandian																																							
			Danian																																							
			Paleocene																																							
Cenomanian																																										
	Albian																																									
		Aptian																																								
				Barremian																																						
			Hauterivian																																							
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	Sinemurian																																									
		Hettangian																																								

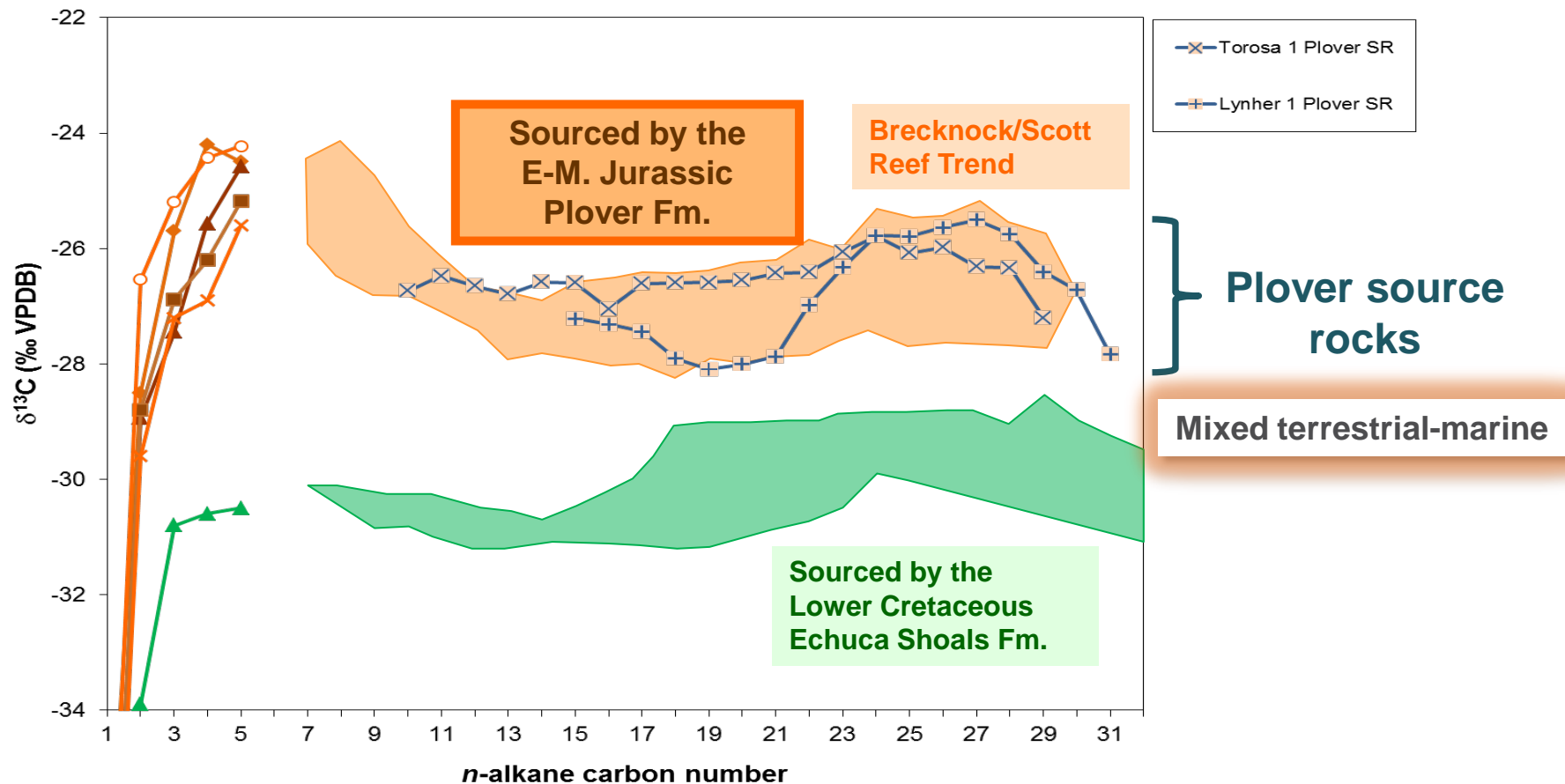
Source of Brecknock/Scott Reef Trend Fluids



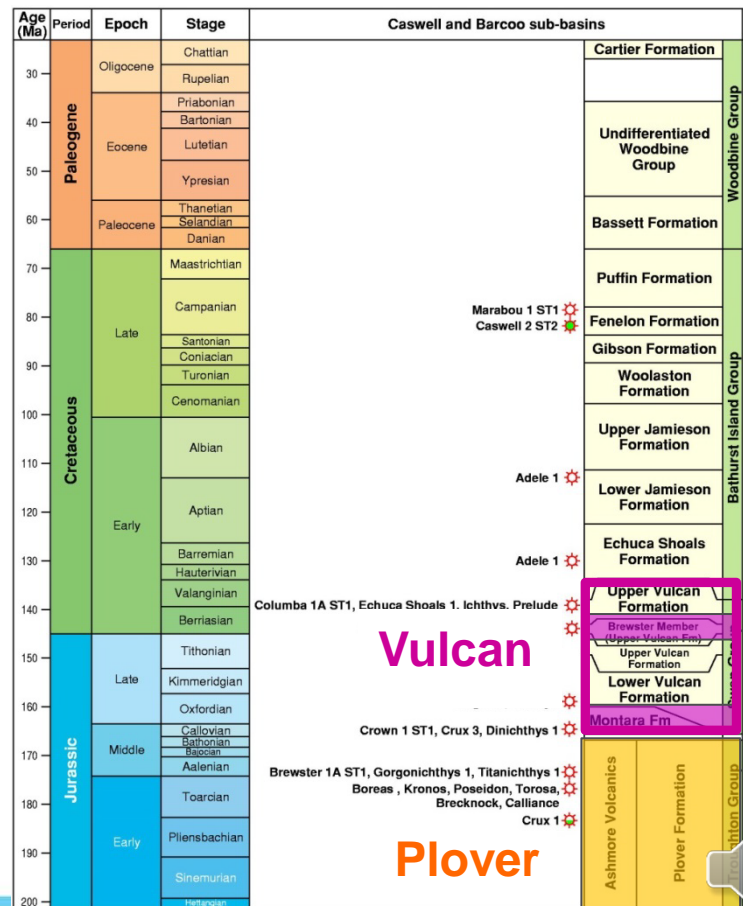
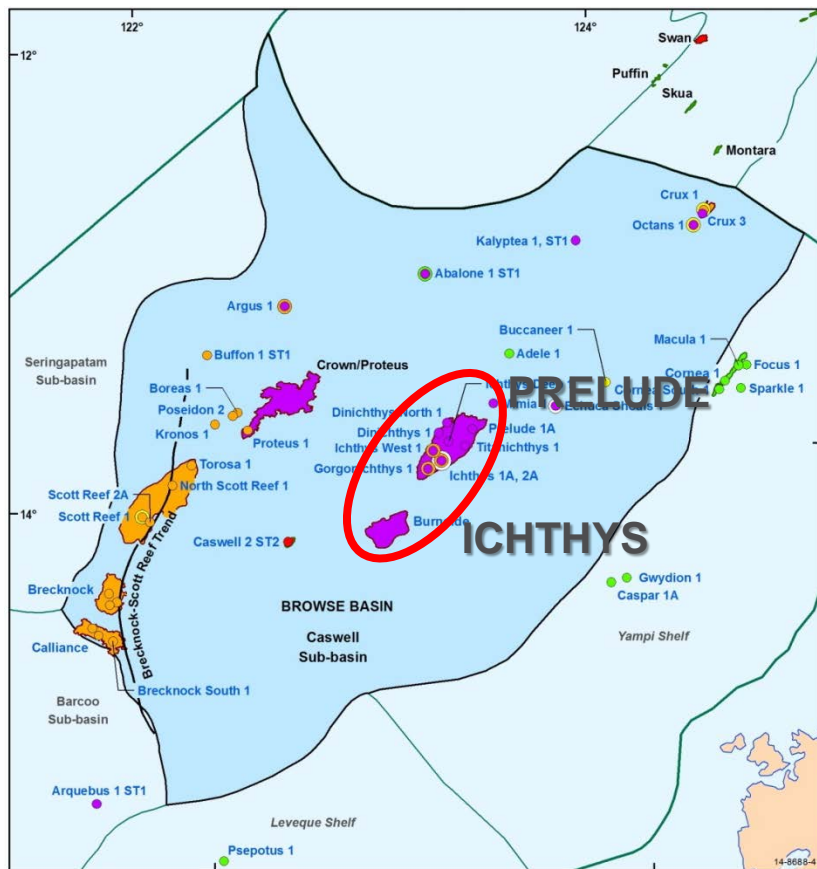
Source of Brecknock/Scott Reef Trend Fluids



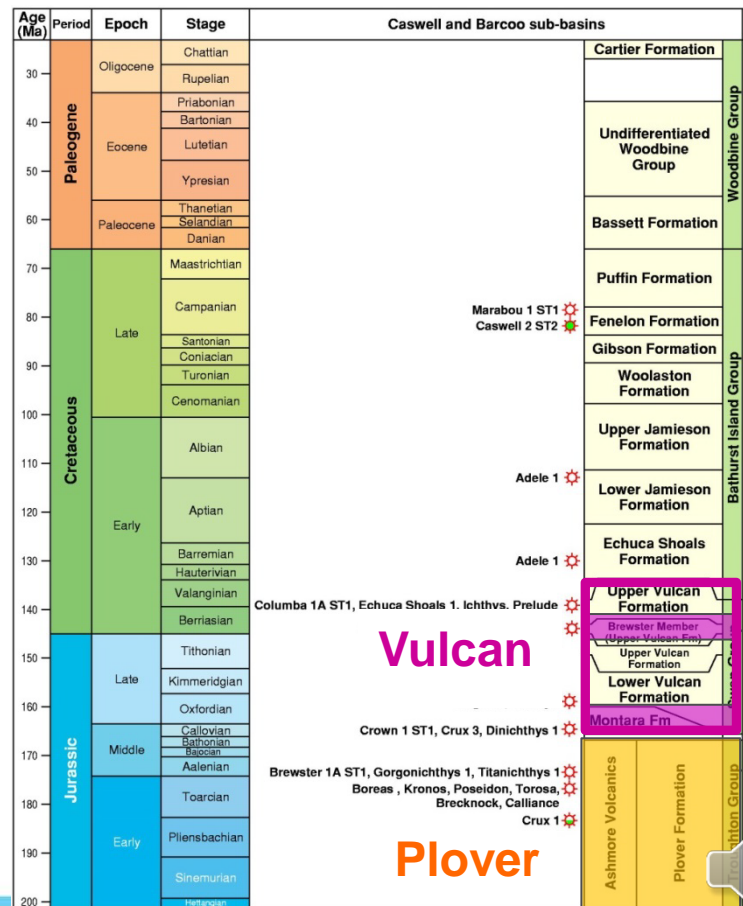
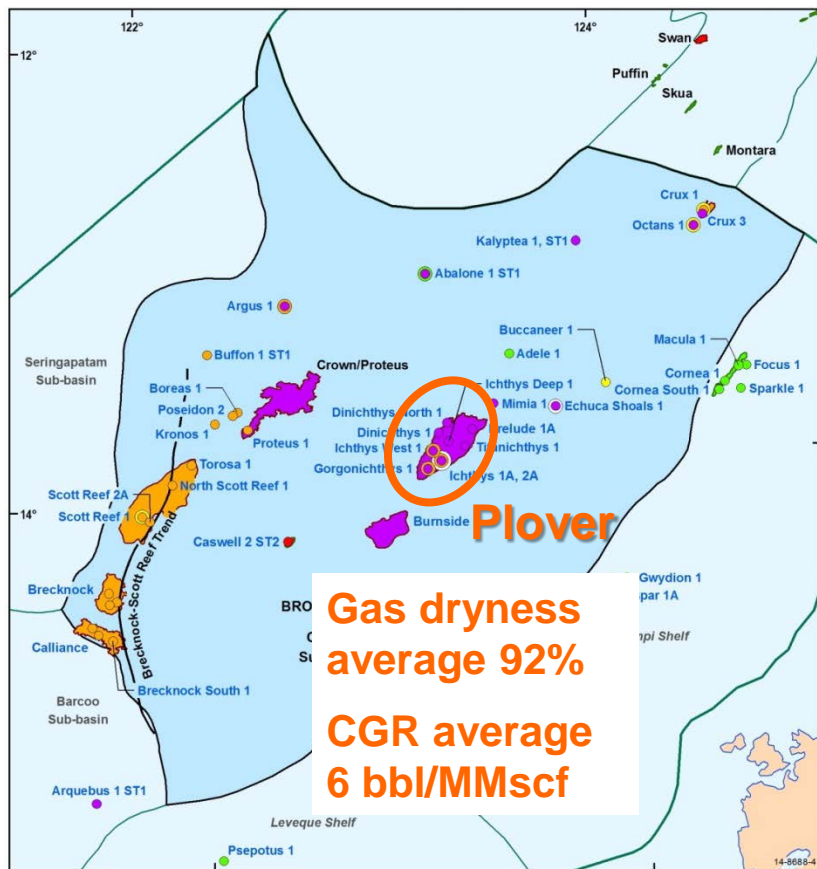
Source of Brecknock/Scott Reef Trend Fluids



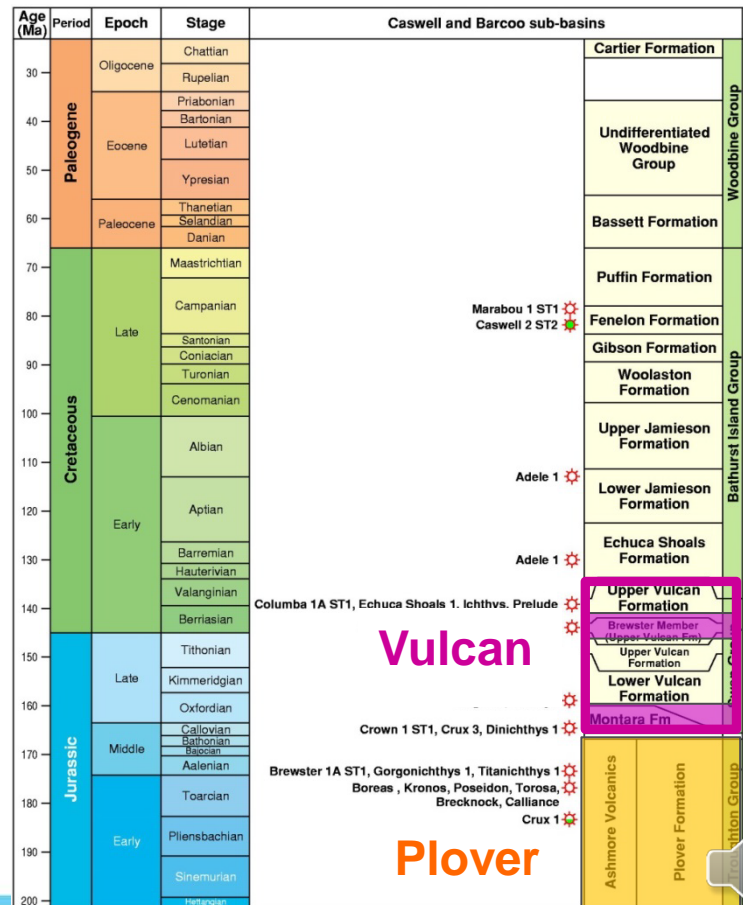
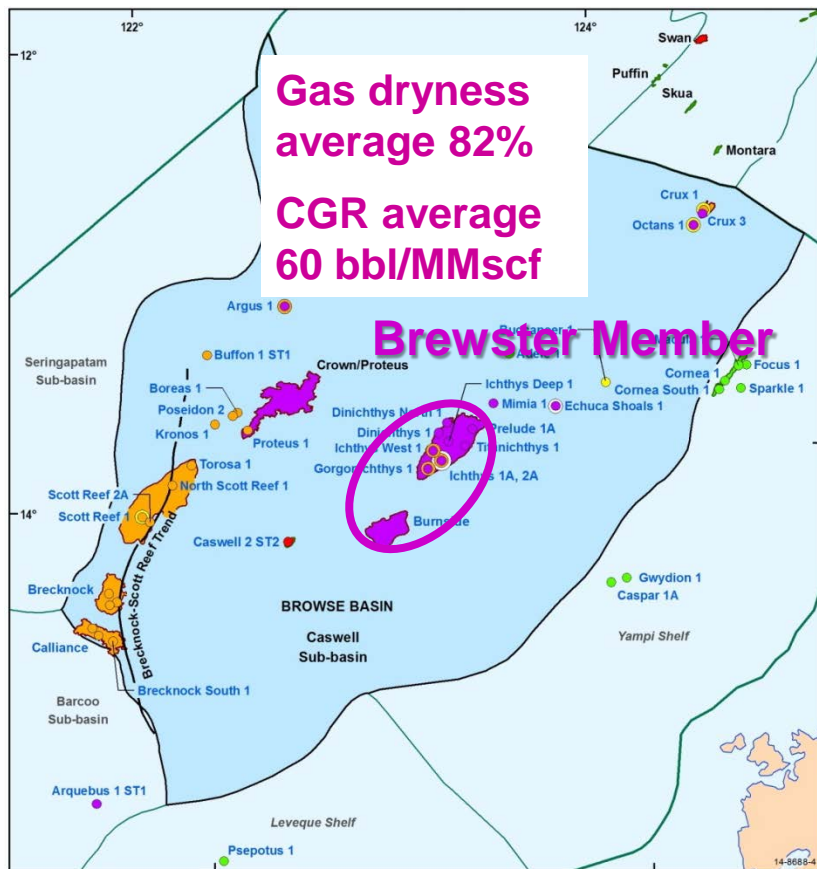
Gas accumulations: Ichthys/Prelude



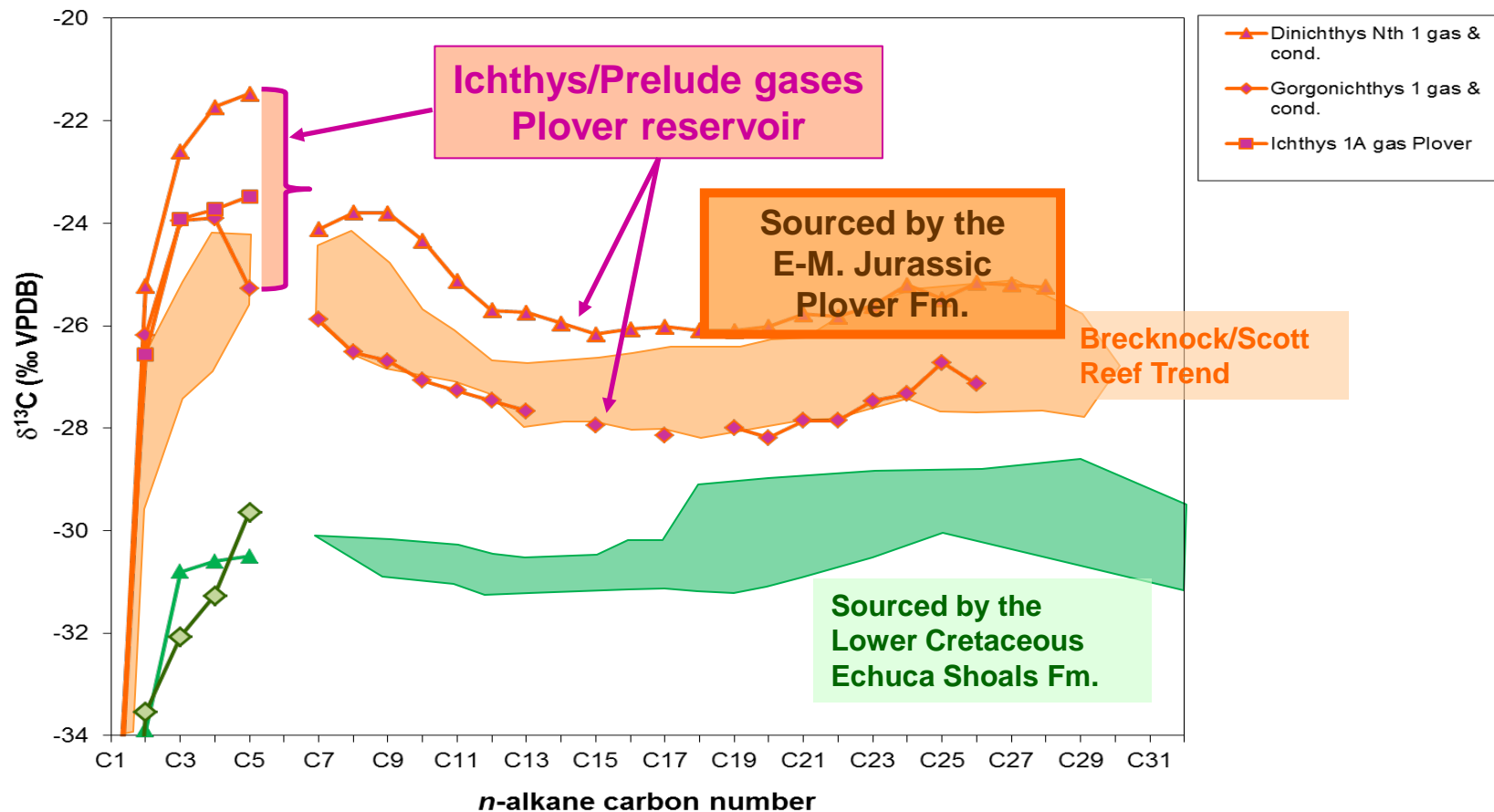
Gas accumulations: Ichthys/Prelude



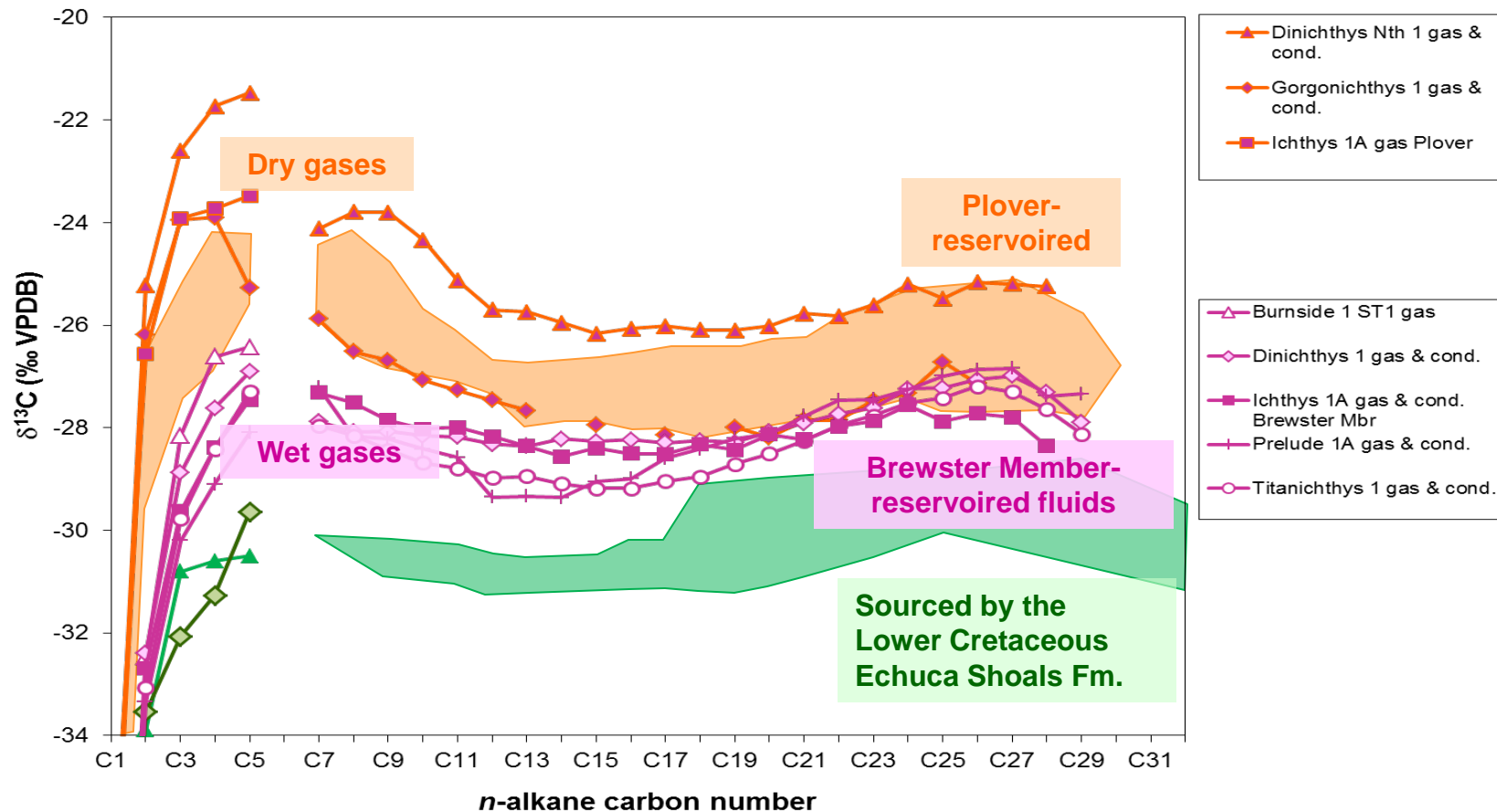
Gas accumulations: Ichthys/Prelude



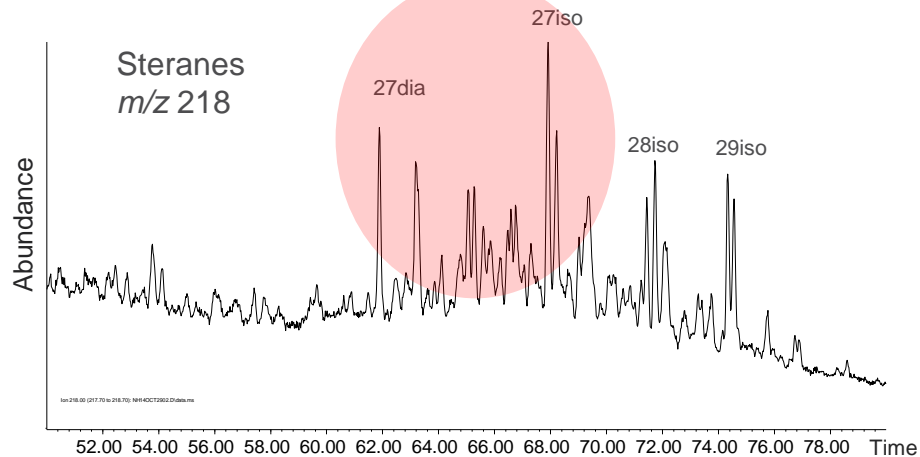
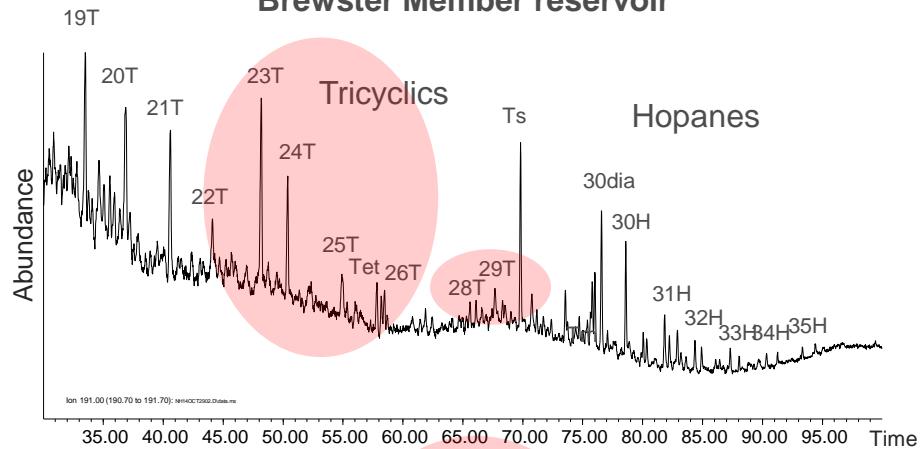
Source of Ichthys/Prelude Fluids: Plover reservoirs



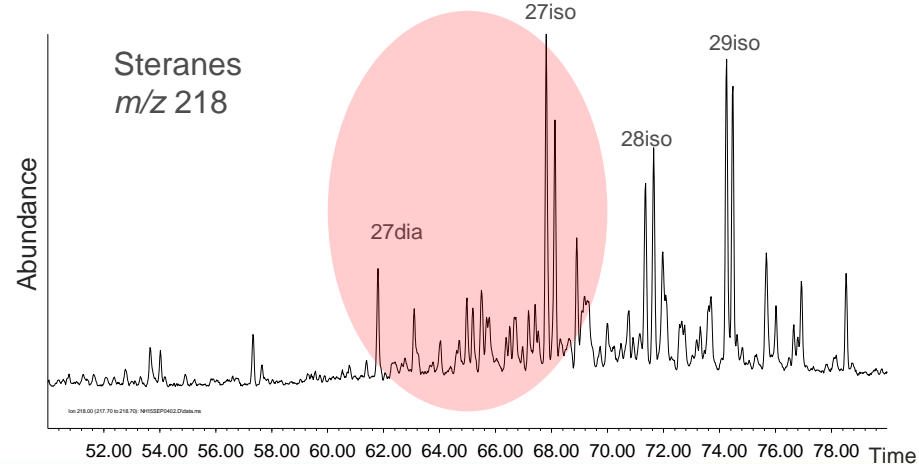
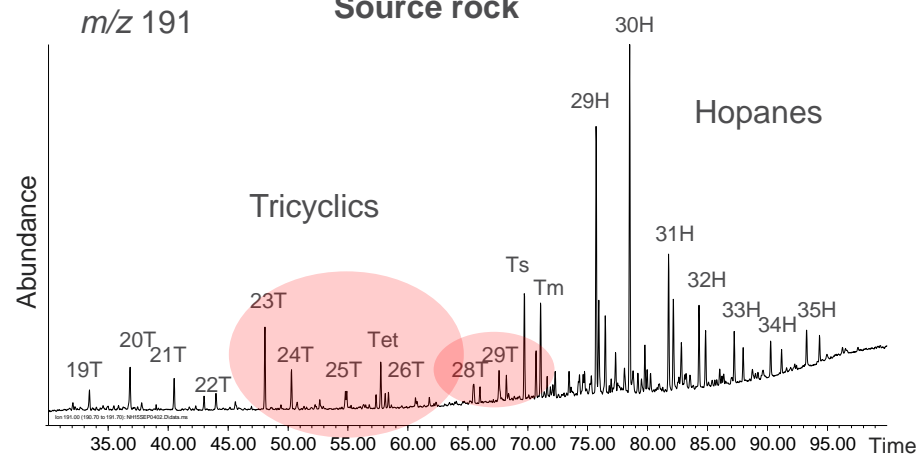
Source of Ichthys/Prelude Fluids: Brewster Member reservoirs



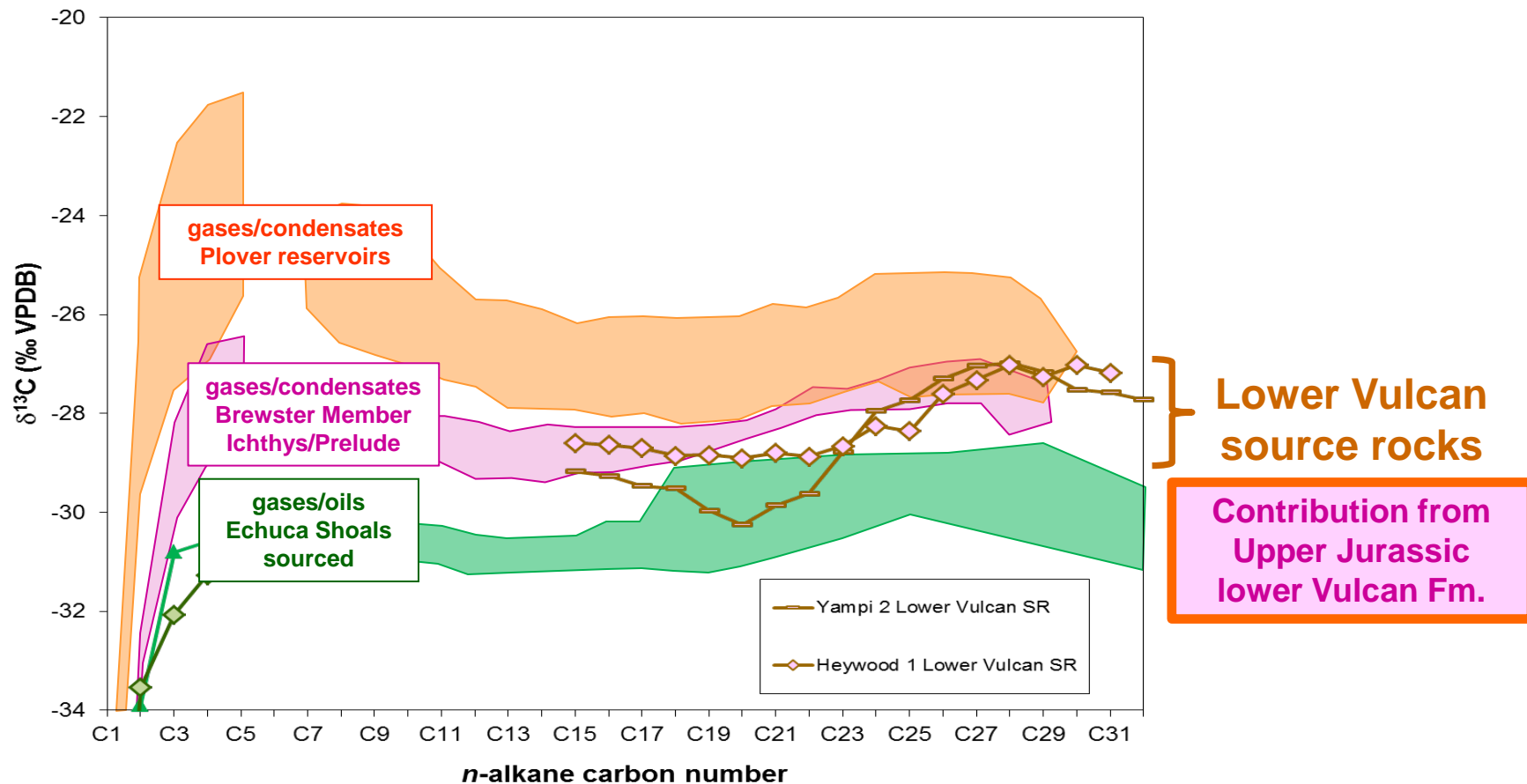
Dinichthys 1 condensate **Brewster Member reservoir**



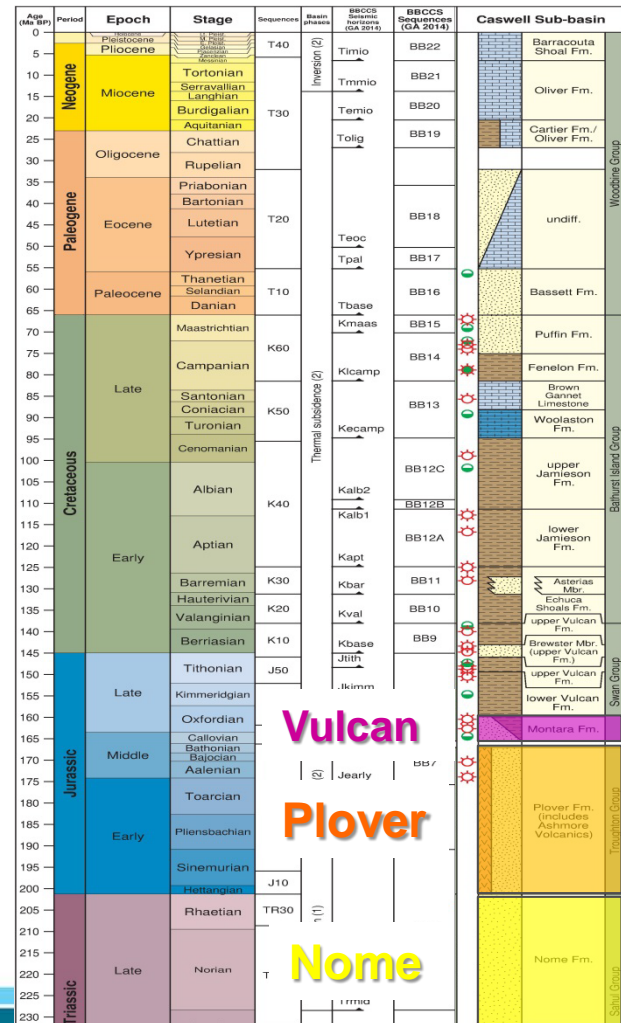
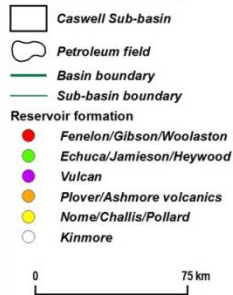
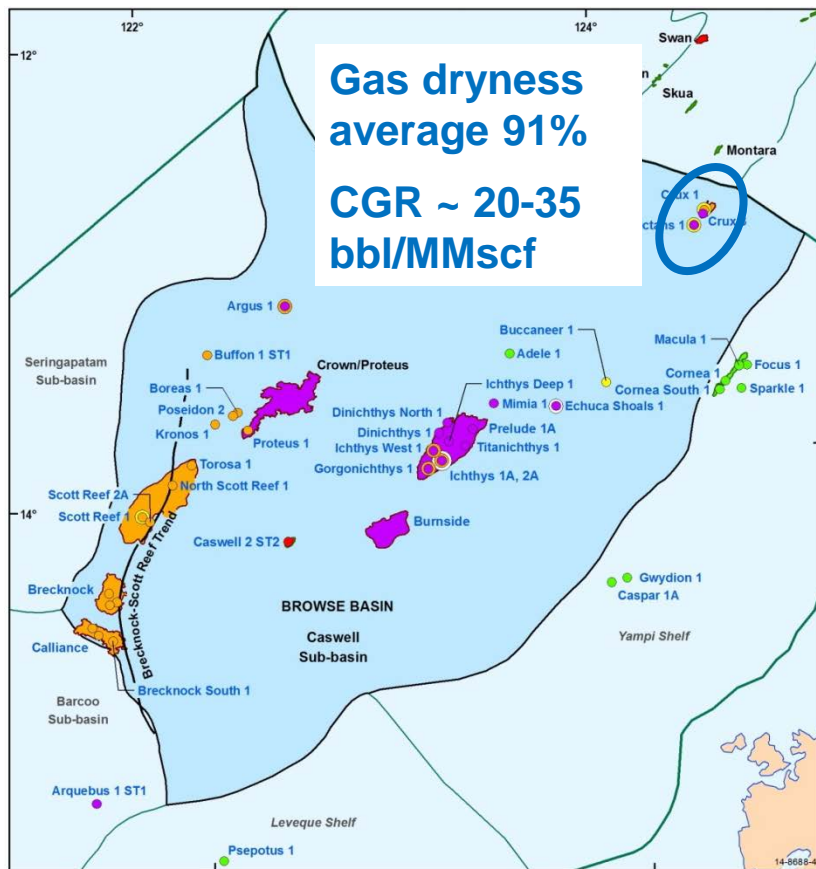
Heywood 1 Lower Vulcan **Source rock**



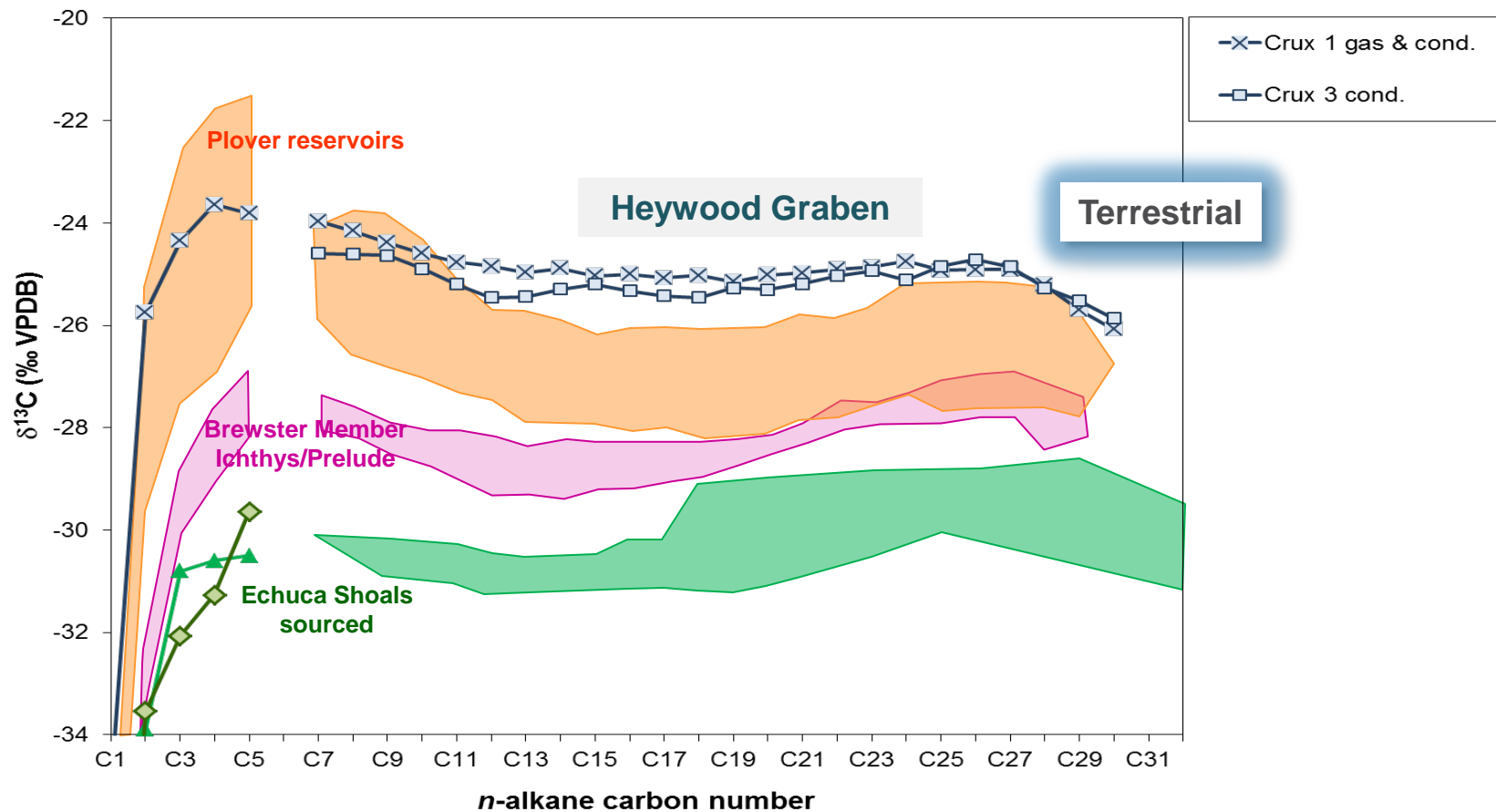
Source of Ichthys/Prelude Fluids: Brewster Member reservoirs



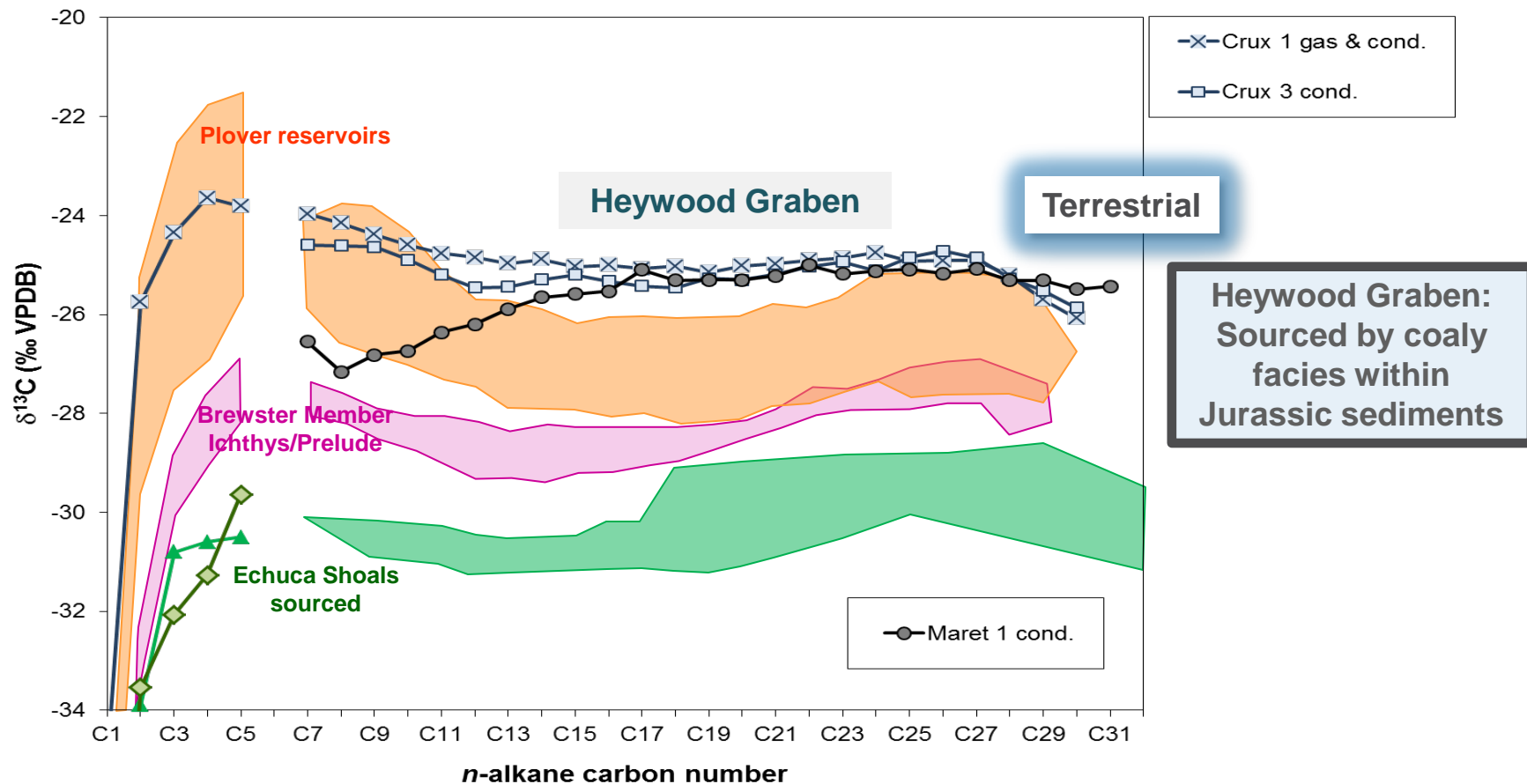
Gas accumulations: Crux field



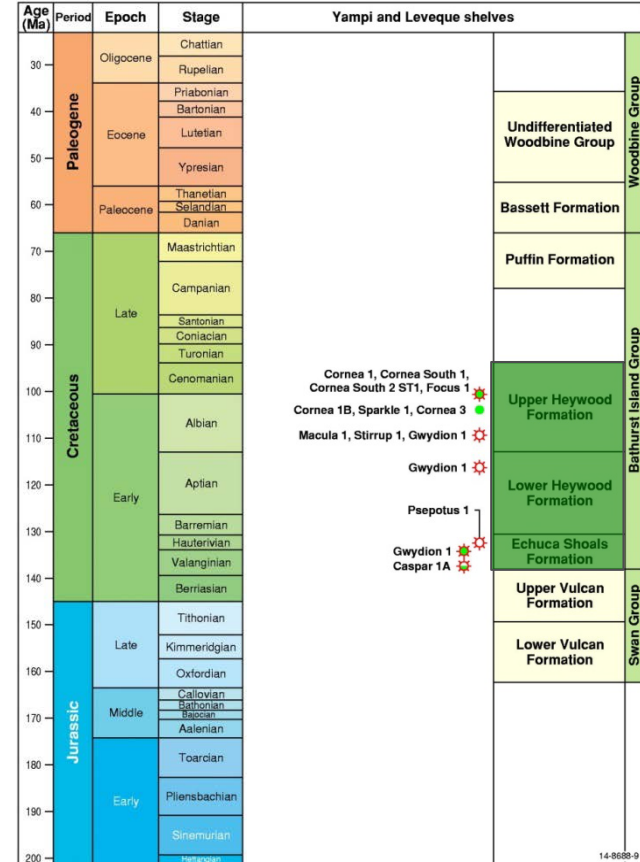
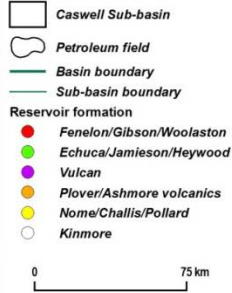
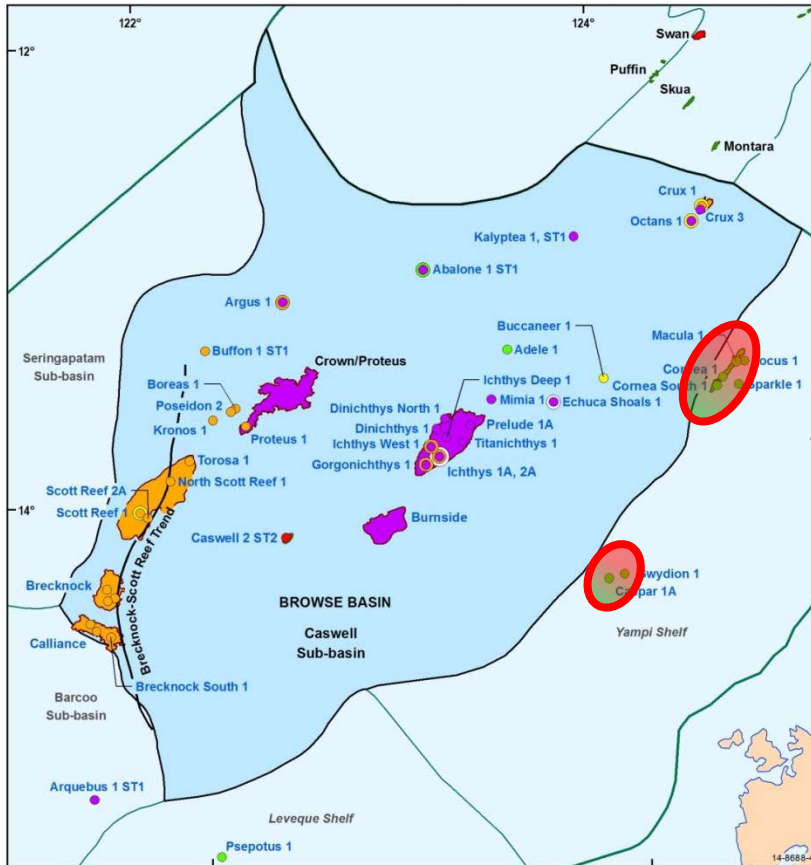
Source of Crux Fluids



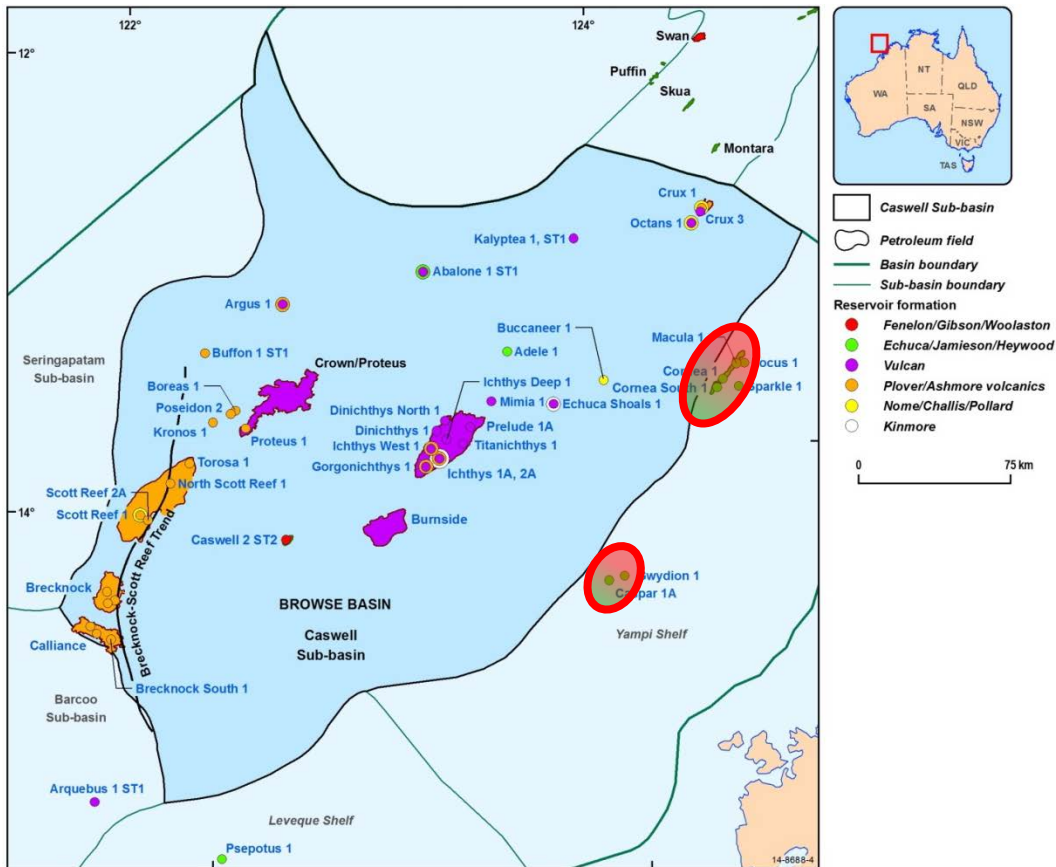
Source of Crux Fluids



Source of gases on Yampi Shelf

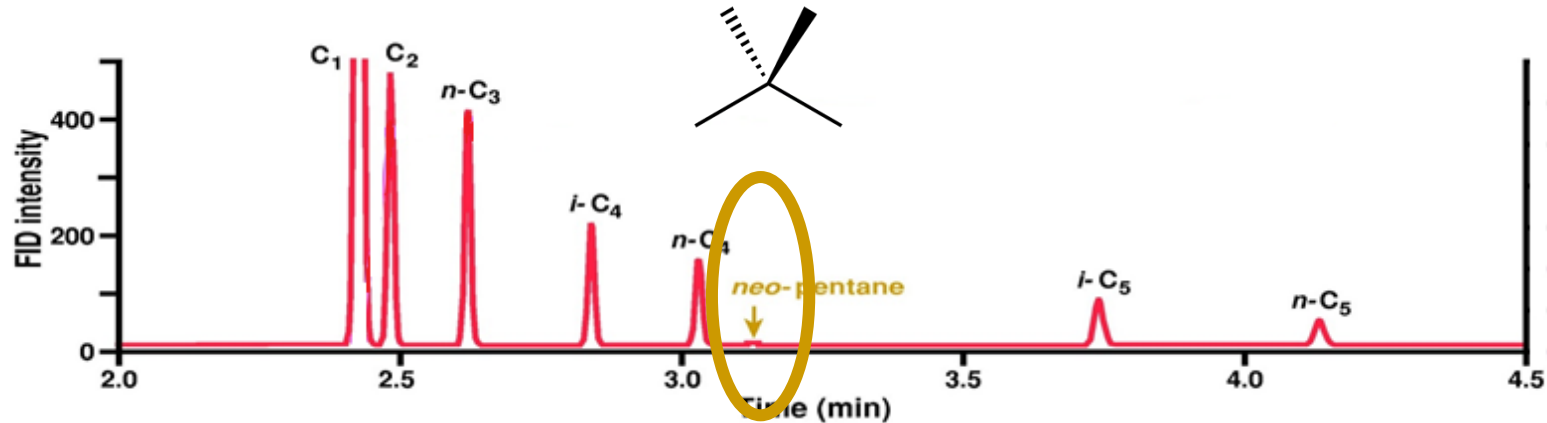


Source of gases on Yampi Shelf



- **Gases very dry**
 - Gas dryness > 98%
- **Shallow reservoirs (< 1000 m)**
- **Oils biodegraded to various extent: Cornea 1/Cornea South 2/Focus 1/Sparkle 1/Gwydion 1**
- **Gases affected by in-reservoir biodegradation**

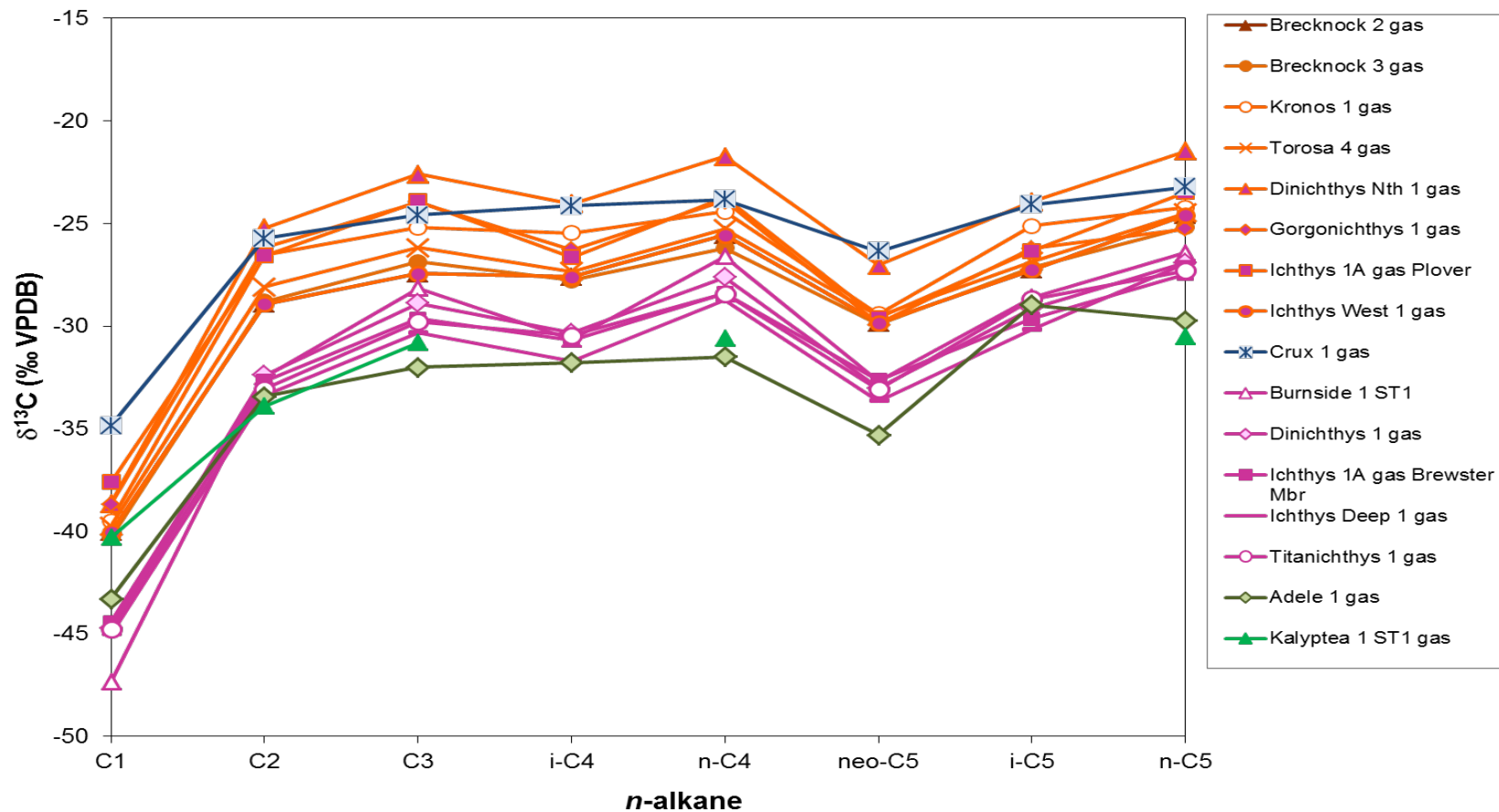
Geochemical analyses of gases: *neo*-pentane



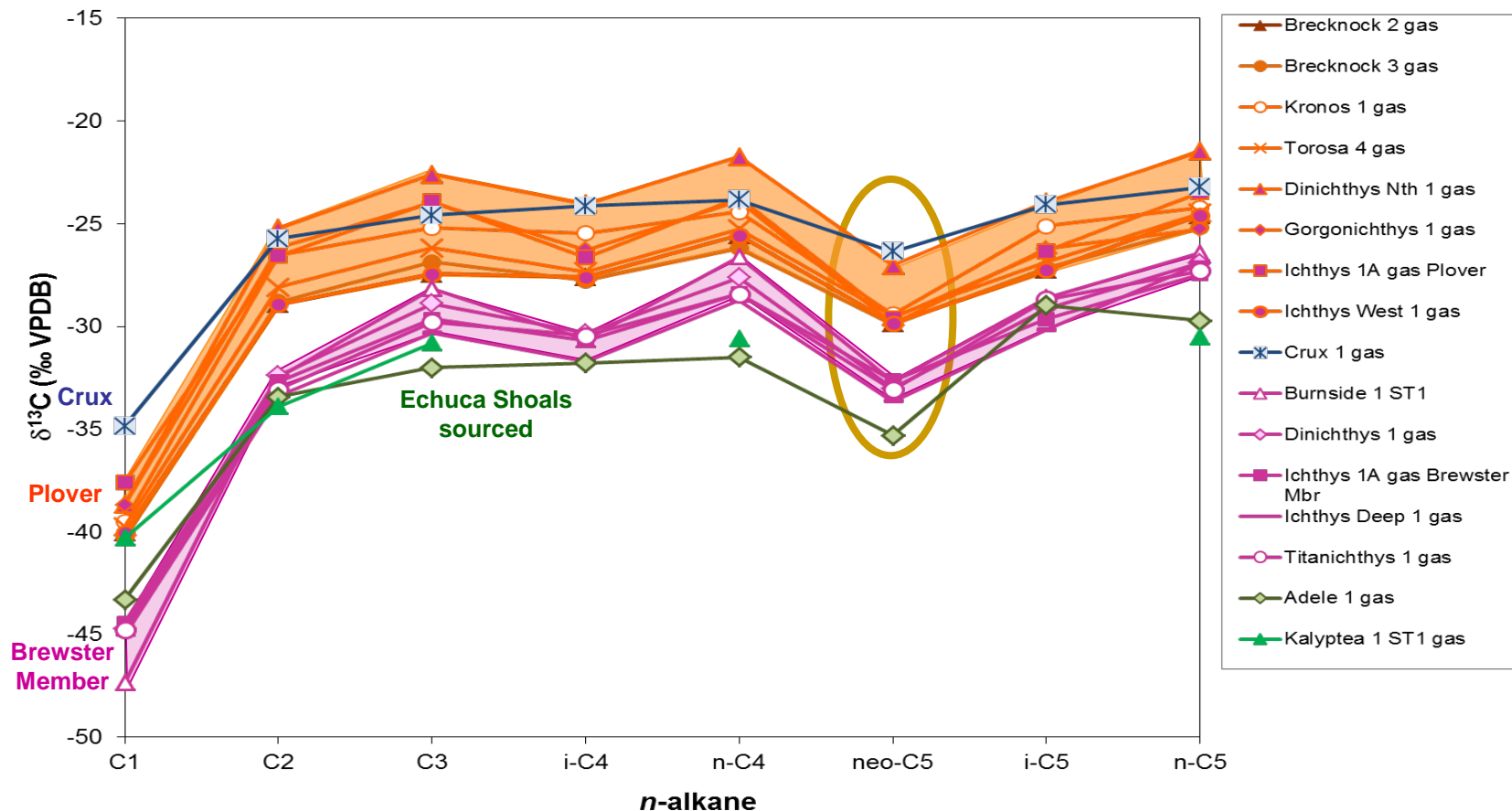
➤ *neo*-pentane (Boreham and Edwards, 2008)

- Resistant to biodegradation
- Excellent source correlation tool

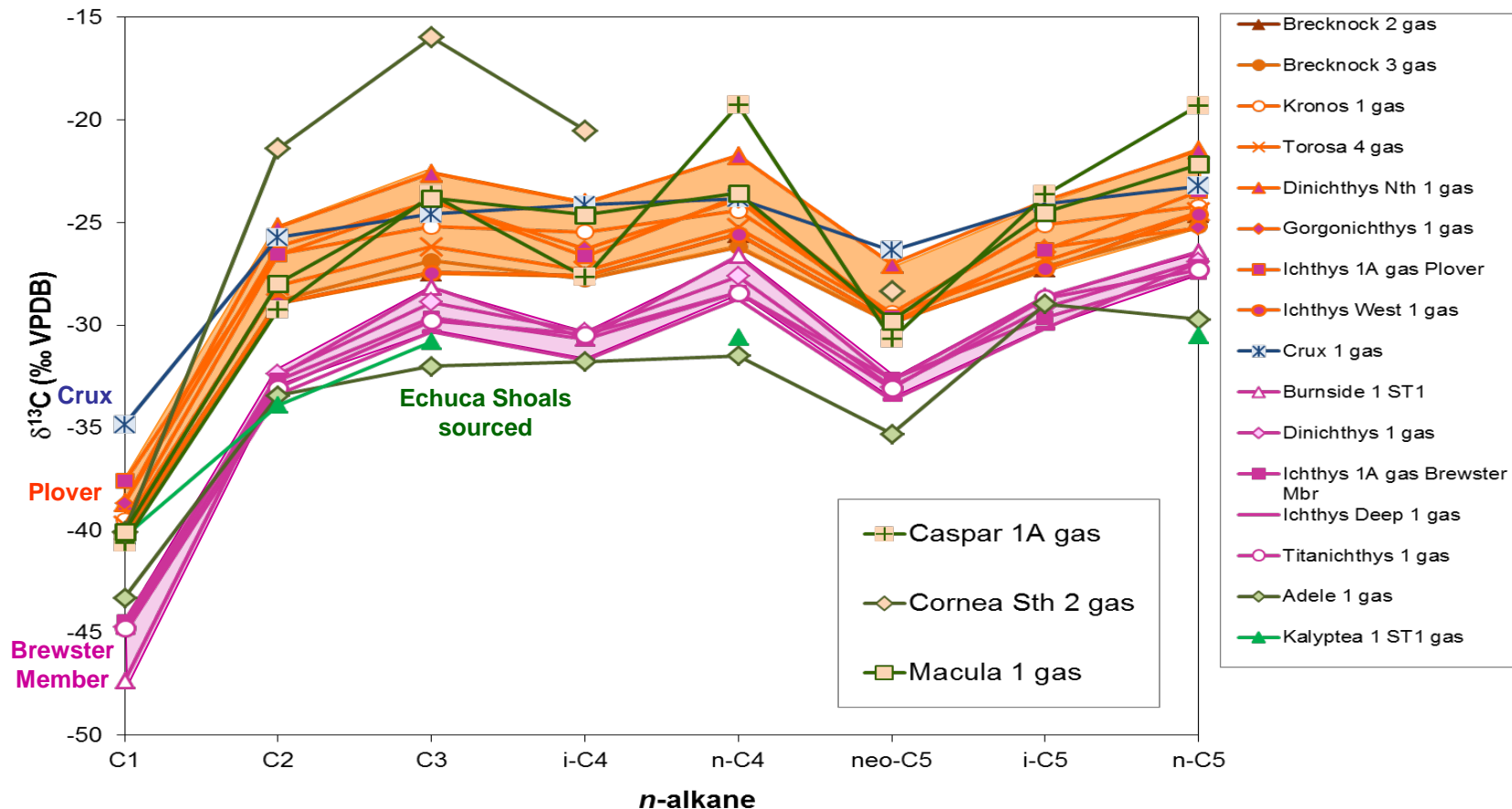
Source of gases on Yampi Shelf



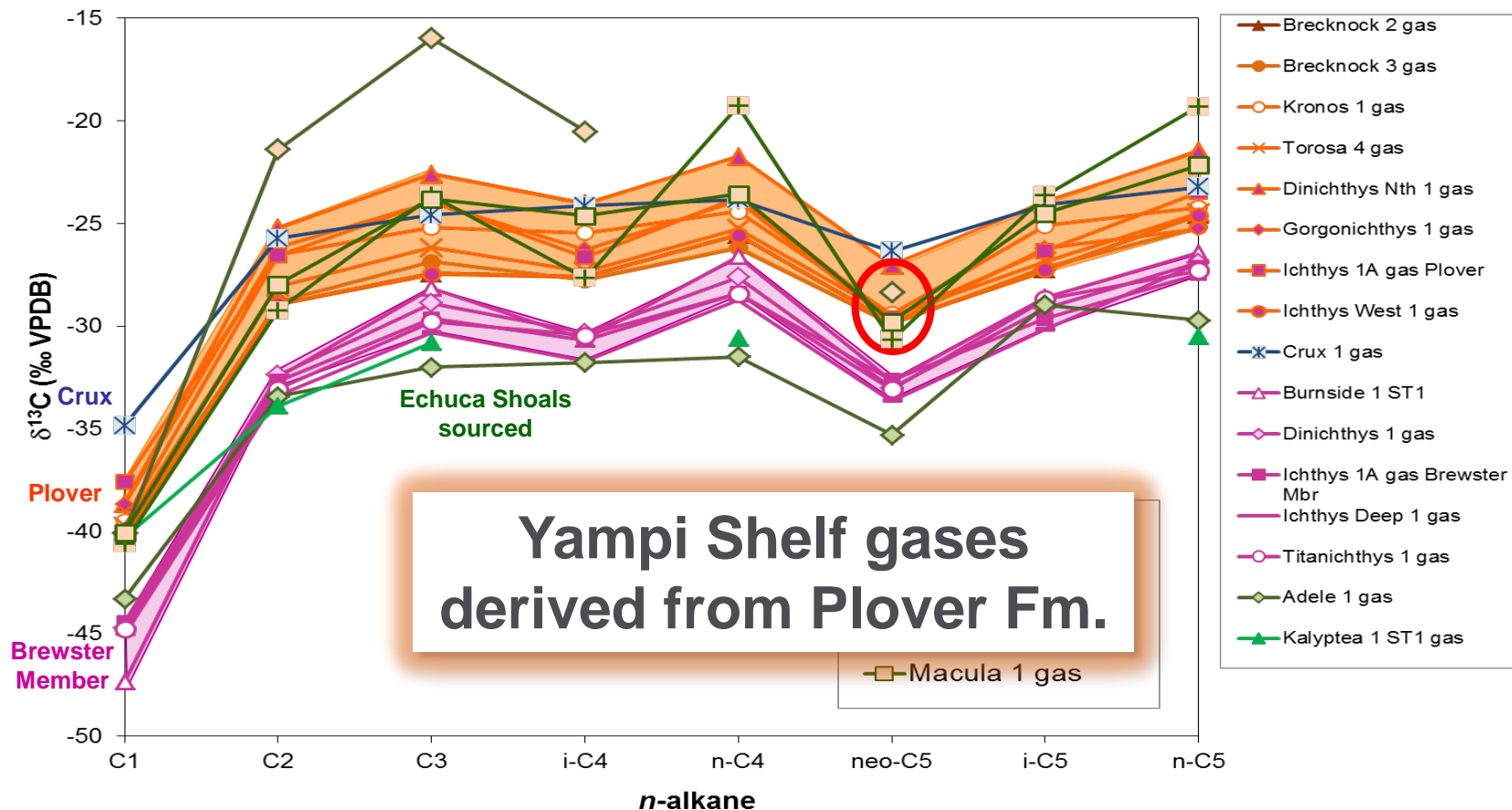
Source of gases on Yampi Shelf



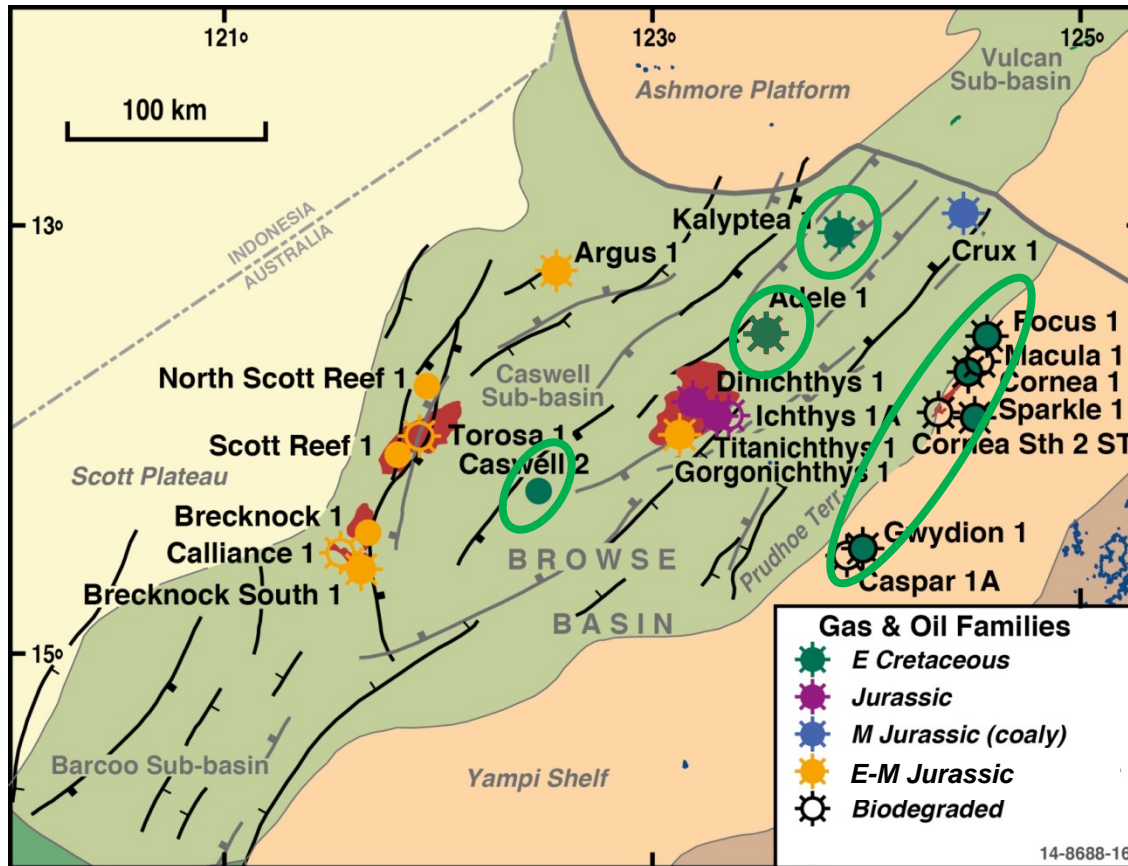
Source of gases on Yampi Shelf



Source of gases on Yampi Shelf



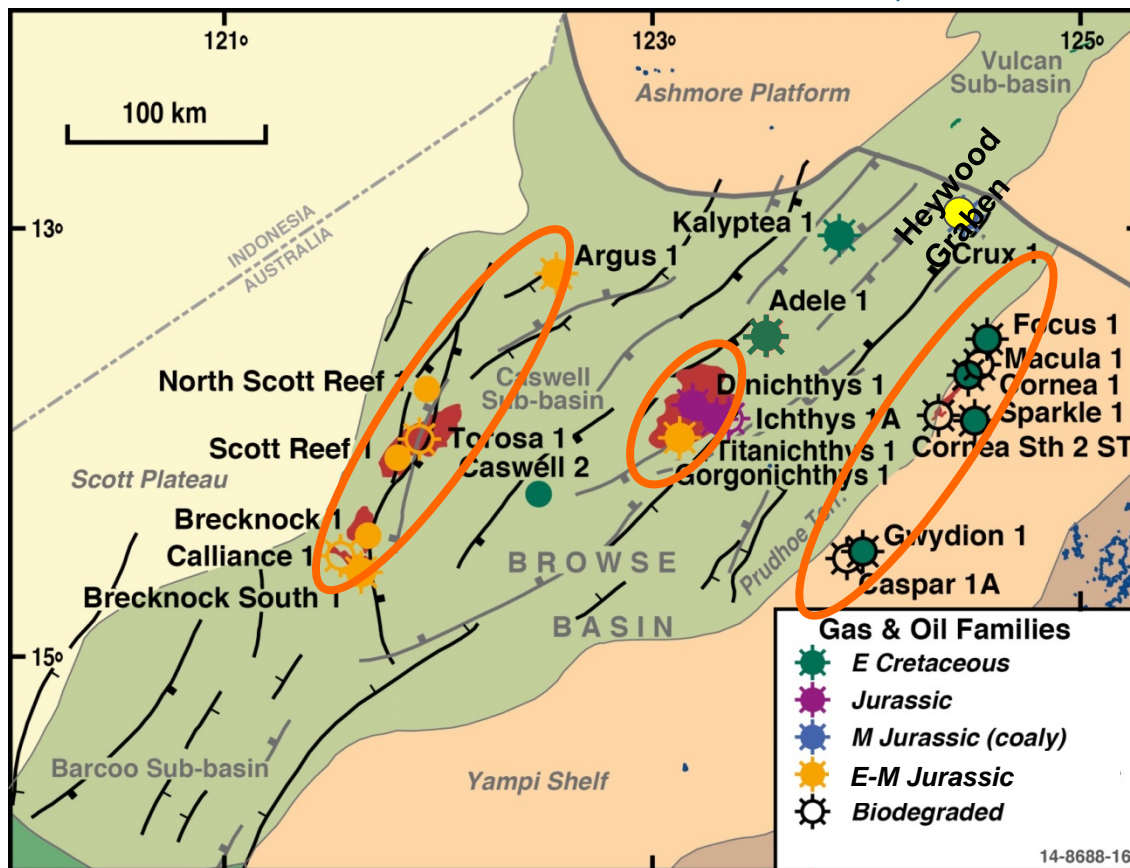
Lower Cretaceous-Sourced Oil and Gas



**Lower Cretaceous
Echuca Shoals-
sourced oil and gas**

Edwards et al, 2006 AAPG

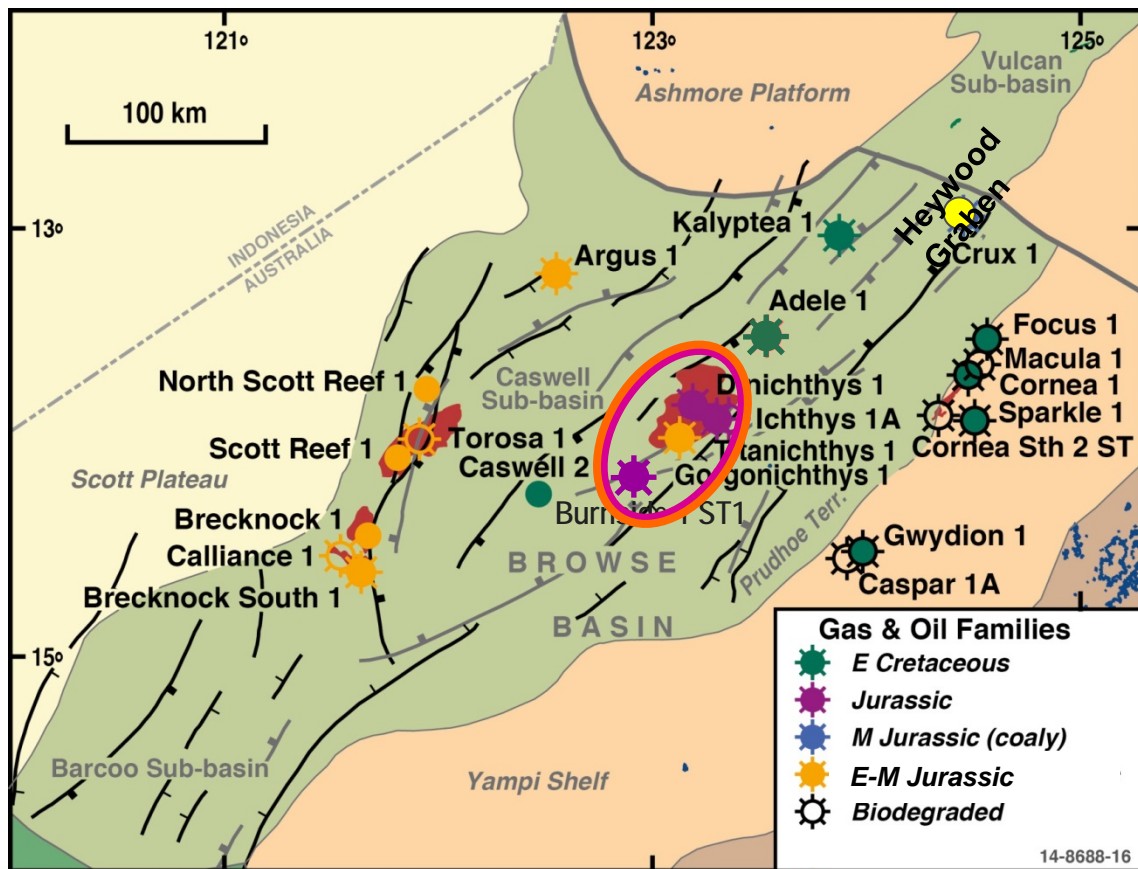
Gas & Condensate Families; Plover-sourced



**Plover-sourced
Dry gas**

Edwards et al, 2006 AAPG

Ichthys Gas & Condensate; Plover/Vulcan sourced

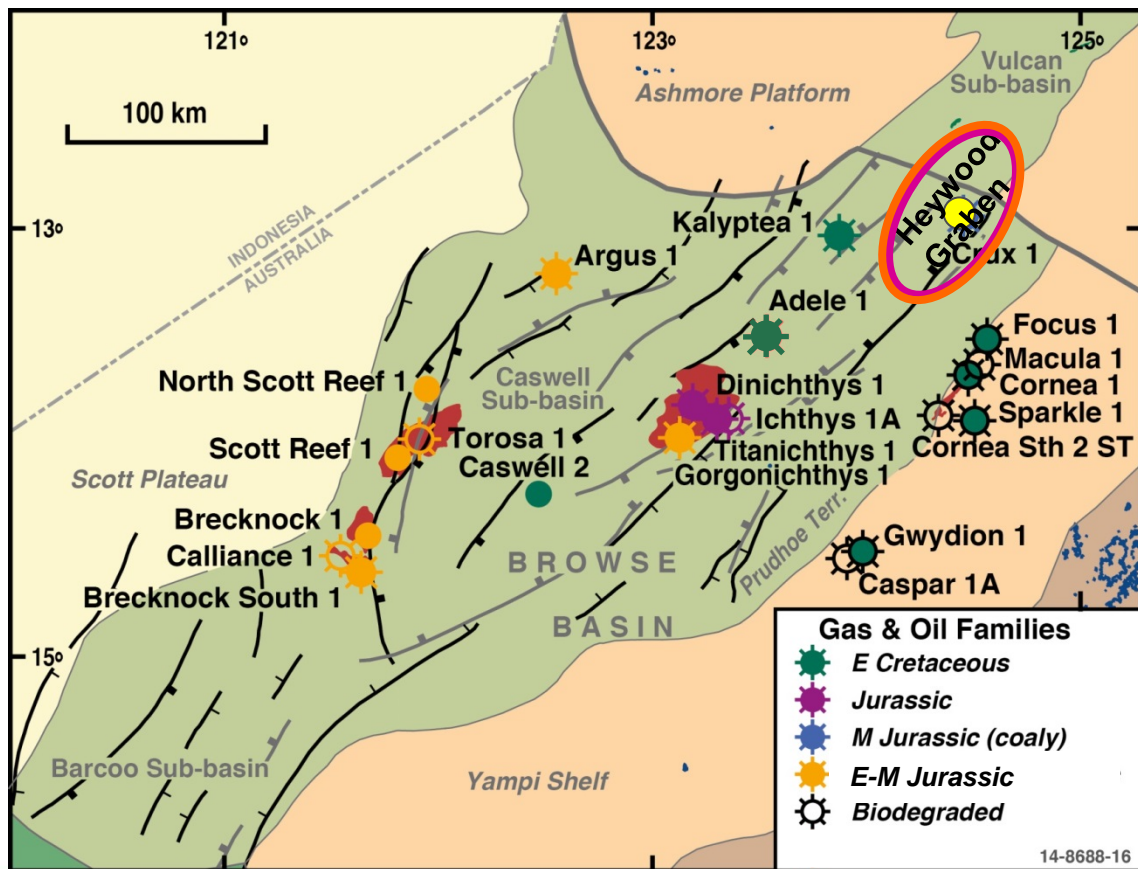


**Brewster Member
reservoirs Ichthys**

**Vulcan- + Plover-
sourced
Wet gases**

Edwards et al, 2006 AAPG

Crux Gas/Condensate; Plover/Vulcan-Sourced



Heywood Graben

Plover & Vulcan-sourced gas

Edwards et al, 2006 AAPG

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Boreham, Chris Nicholson, Steve Lepoidevin, Victor Nguyen,
Jennie Totterdell, Jamie Lankford (Geoscience Australia)

Andrew Murray (Murray Partners)

Paul Stephenson (GSWA)

More on the Browse Basin from Geoscience Australia

→ C. Nicholson et al. in CO₂ Storage: Results Thus Far - Tuesday morning (presentation)

Browse Basin 2014 Marine Survey—Investigating Containment for Potential Late Cretaceous CO₂ Storage Plays

→ N. Rollet et al. in CO₂ Storage: Site Selection - Tuesday afternoon (presentation)

Cretaceous Stratigraphic Play Fairways and Risk Assessment in the Browse Basin: Implications for CO₂ Storage

→ S. T. Abbott et al. in Seismic Stratigraphy - Tuesday afternoon (presentation)

Seven Cretaceous Low-Order Depositional Sequences From the Browse Basin, North West Shelf, Australia: A Framework for CO₂ Storage Studies

→ M. E. Lech et al. in Marita Bradshaw – Palaeographic Evolution of Oz - Tuesday morning (poster)

Paleogeographic Evolution of Early Campanian to Maastrichtian Supersequences in the Caswell Sub-Basin—Implications for CO₂ Storage and Hydrocarbon Entrapment

Thank you

Any questions?

Resources Division

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