[PS]Encased Secondary Minibasins: an Emerging Play in the Deepwater Gulf of Mexico*

Ursula Edwards[1], Vernon Moore[1], and Ugojoh Odumah[1]

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Abstract

Advances over the last several years in seismic acquisition (wide azimuth, rich azimuth, and coil shooting) and processing (reverse time migration and full waveform inversion) have led to increased recognition of encased secondary minibasins in the central Deepwater Gulf of Mexico. An understanding of the spatial and temporal distribution and development of encased minibasins expands our regional understanding of salt tectonics and salt-sediment dynamics and may provide new exploration targets. Encased basins form when allochthonous salt flows completely over the top of the minibasin during times of low deposition relative to the adjacent salt inflation. Two types of encased basins are recognized: (1) Basins overridden by salt early in their development, in which encasement occurs long before welding at the base or sides of the basin; these basins appear to have subsided or capsized within an inflating salt canopy, with some subsiding into an open diapir or having a younger basin stacked on top, and (2) Basins overridden by salt late in their development, in which encasement occurs near or after the time of welding at the base or sides of the basin; these basins do not appear to have capsized or subsided significantly into the salt and were instead encased by salt evacuating from beneath neighboring subsiding basins. Secondary basins deposited during the Miocene in the central Gulf of Mexico were prone to encasement in the Early Pliocene. Basins encased in the Pleistocene are observed, but appear to be less common. Wells penetrating encased basin section in the central Gulf of Mexico have encountered a variety of circumstances such as thick wet sands, unexpectedly young section, or steep dips. Many of these wells were drilled prior to imaging advances and were thus poorly positioned relative to prospective closures. The recognition of the presence and widespread distribution of encased basins enhanced depth imaging of adjacent primary section exploration targets by including the properties of the encased basin section into velocity models.

Encased Secondary Minibasins: an Emerging Play in the Deepwater Gulf of Mexico

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Global Exploration: Gulf of Mexico, Marathon Oil Company

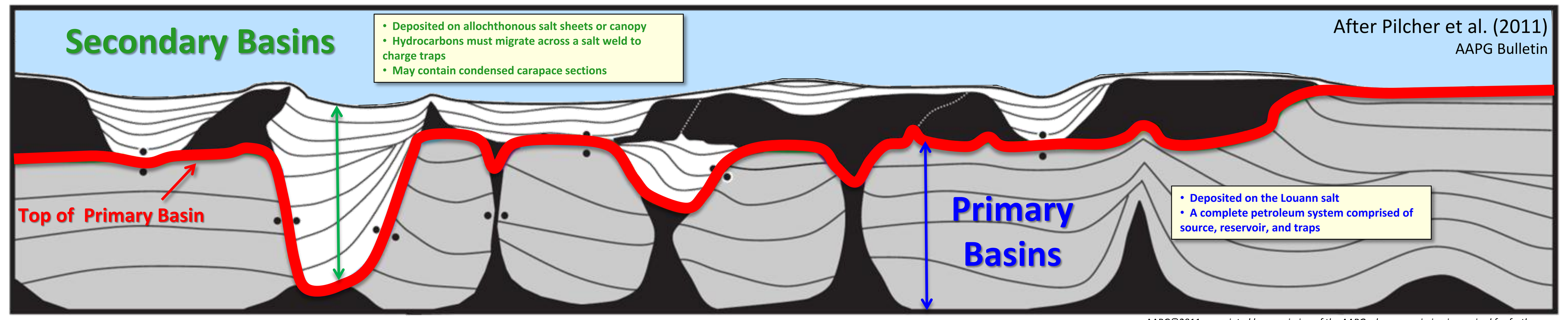
Marathon Oil

Abstract

Advances over the last several years in seismic acquisition (wide azimuth, full azimuth, and long offset) and processing (reverse time migration and full waveform inversion) have led to increased recognition of encased secondary minibasins in the central Deepwater Gulf of Mexico. An understanding of the spatial and temporal distribution and development of encased minibasins expands our regional understanding of salt tectonics and salt-sediment dynamics, and may provide new exploration targets. Encased basins form when allochthonous salt flows completely over the top of the minibasin during times of low deposition relative to the adjacent salt inflation. Two types of encased basins are recognized: (1) Basins in which encasement occurs before welding at the base or sides of the basin; these basins appear to have subsided or capsized within an inflating salt canopy, with some subsiding into an open diapir or having a younger basin stacked on top, and (2) Basins in which encasement occurs near the time of welding at the base or sides of the basin; these basins do not appear to have capsized or subsided significantly into the salt and were instead encased by salt evacuating from beneath neighboring subsiding basins. Secondary basins deposited during the Miocene in the central Gulf of Mexico were prone to encasement in the Early Pliocene. Basins encased in the Pleistocene are observed, but appear to be less common. Wells penetrating encased basin section in the central Gulf of Mexico have encountered a variety of scenarios such as various lithologies, ages, and dips. Many of these wells were drilled prior to recent imaging advances and were thus poorly positioned relative to prospective closures. The recognition of the presence and widespread distribution of encased basins has enhanced depth imaging of adjacent primary section exploration targets by incorporating the properties of the encased basin section into velocity models.

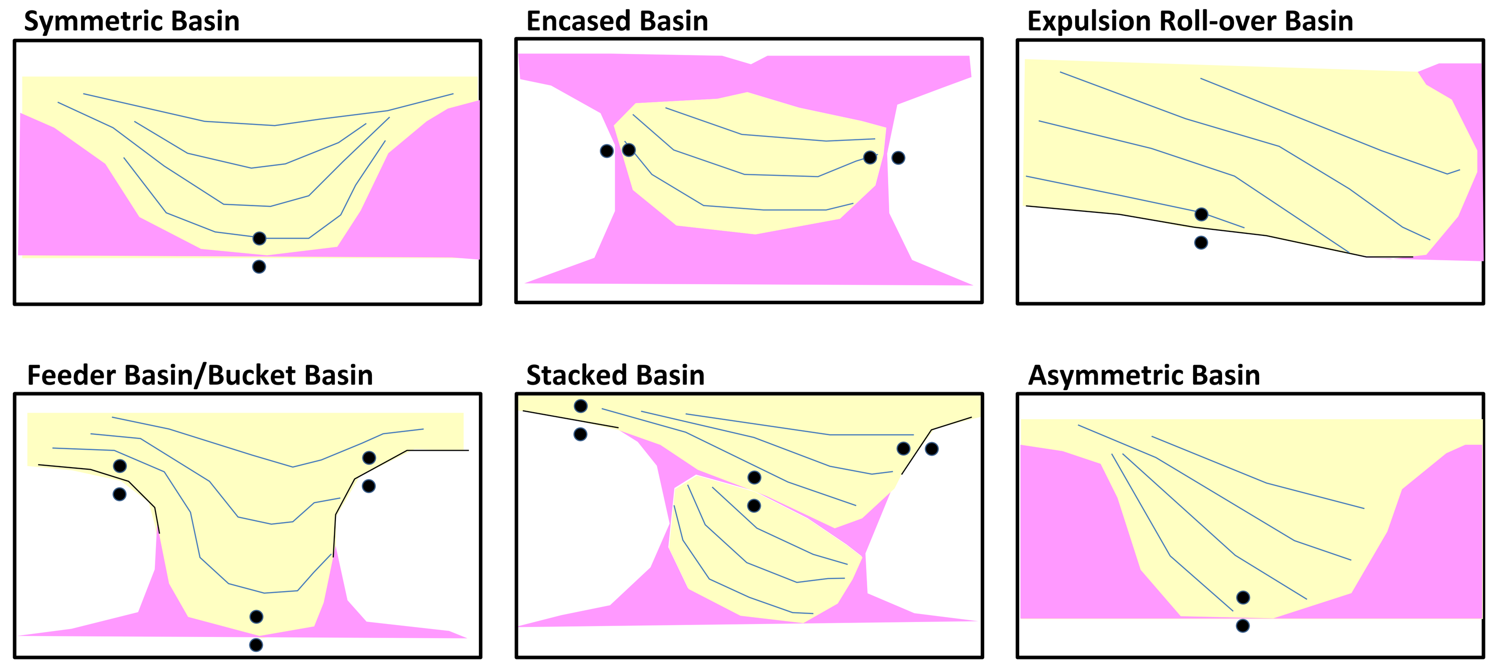
Introduction

A continuum of sediment exists that can become encased in salt canopies and feeders ranging from smaller suture related inclusions, to diapir roof and carapace sections of various thicknesses, to entire minibasins (e.g., Pilcher et al. 2011; Rowan and Inman, 2011; Dooley et al., 2012). It is the purpose of this investigation to describe encased basins that formed through normal minibasin depositional processes and are of significant thickness. Even within this definition, large variations in geometries, weld characteristics, and relative timing of encasement versus foundering are observed.



Observed Structural Styles of Secondary Basins

- Symmetric basins with stacked depocenters
- Basins welded on top of the primary basin section
- Basins that have subsided into a salt feeder, some extending down to the autochthonous salt level (aka "bucket weld" basins)
- Basins encased in salt
- Stacked basins separated by a weld or salt
- Expulsion roll-over basins
- Basins with highly asymmetric growth stratigraphy



Moore and Hinton (2013)

Atlas of Select Encased Secondary Basins and Industry Activity

3 — Prospect – Sale 222

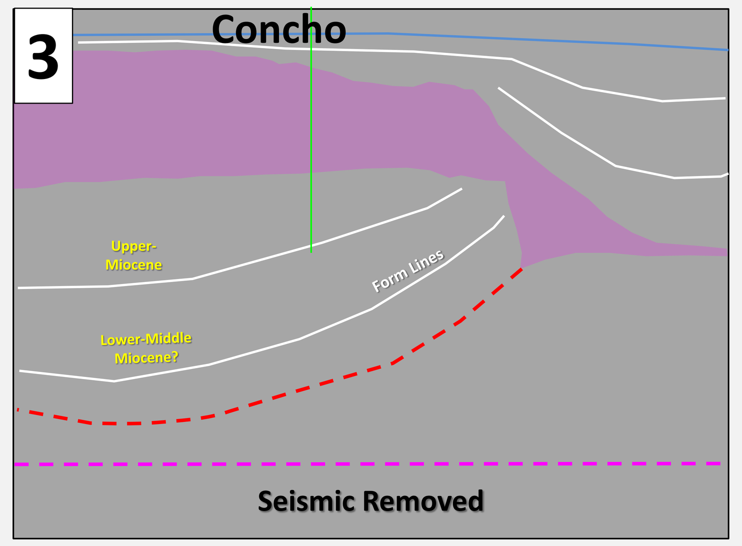
Total High:	$42 MM
Total $ Exposed	$72 MM

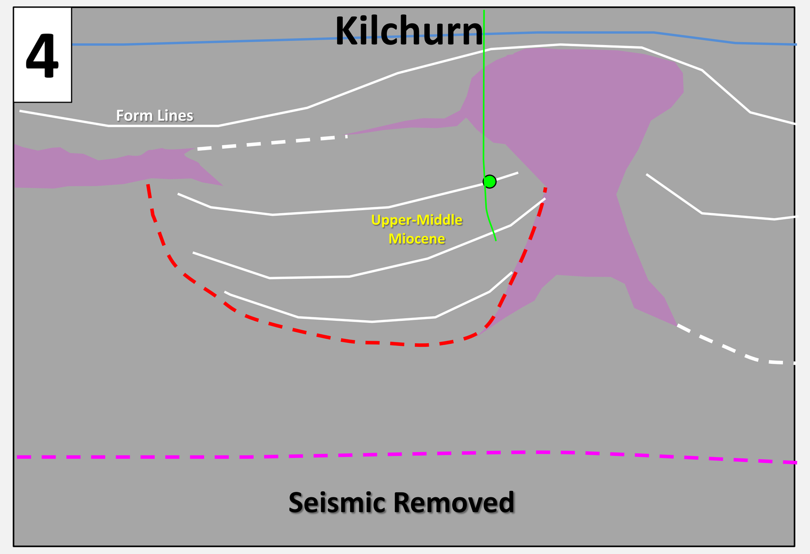
GC 486 – 4 Bids

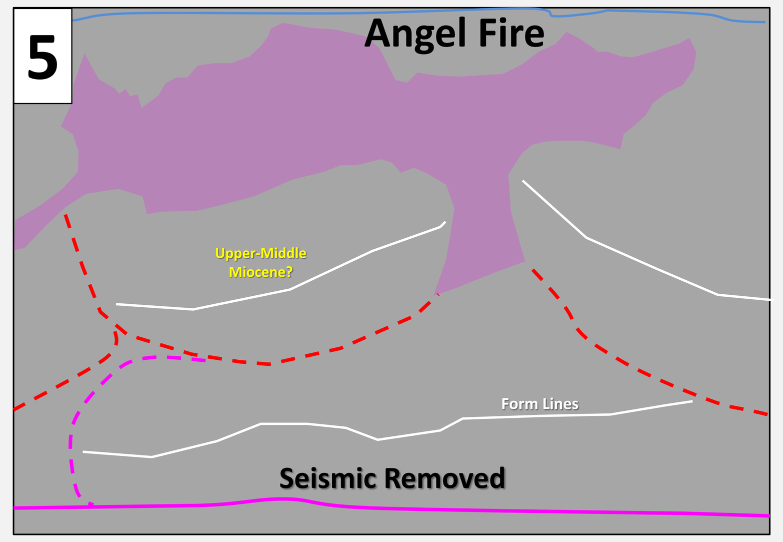
Statoil	**$30.20 MM**
Repsol et al	$11.47 MM
Apache	$ 4.01 MM
BHP	$ 0.70 MM
Total Exp	*$46.39 MM*

GC 487 – 3 Bids

Repsol et al	**$11.47 MM**
Statoil	$ 8.20 MM
Apache	$ 6.01 MM
Total Exp	*$25.68 MM*







5 — Angel Fire – Sale 227

Total High:	$99.65 MM
Total $ Exposed	$120.58 MM

GC 326 – 3 Bids

XOM	**$25.25 MM**
Maersk	$8.30 MM
Murphy/Ecopetrol	$5.42 MM
Total Exp	*$38.97 MM*

GC 327 – 3 Bids

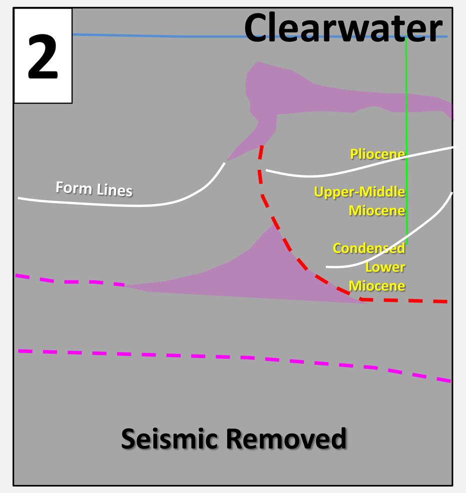
XOM	**$43.10 MM**
Murphy/Ecopetrol	$24.18
Maersk	$8.30 MM
Total Exp	*$38.97 MM*

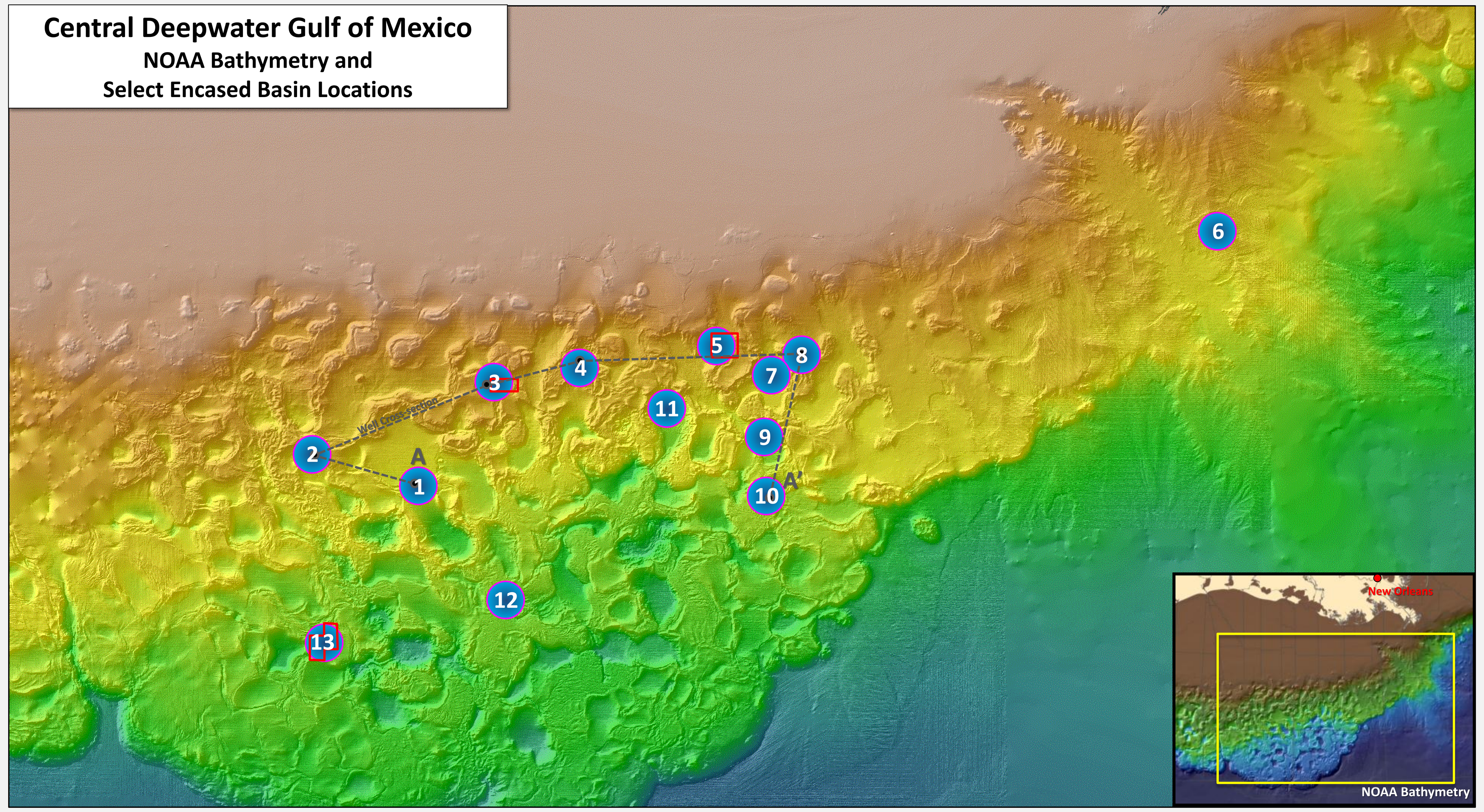
GC 370– 2 Bids

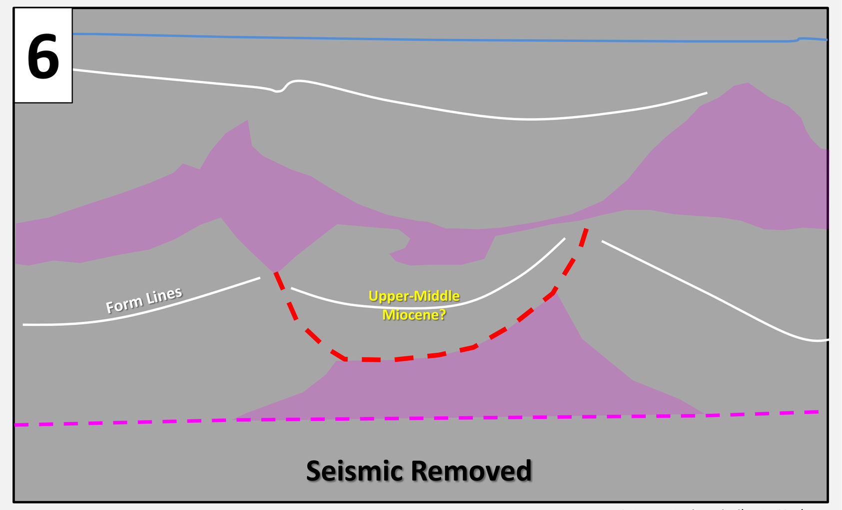
XOM	**$9.2 MM**
Maersk	$1.04 MM
Total Exp	*$10.24 MM*

GC 371 – 3 Bids

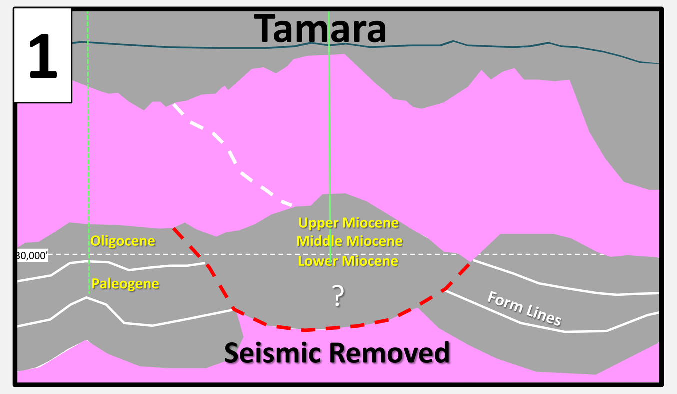
XOM	**$22.1 MM**
Maersk	$8.3 MM
Murphy/Ecopetrol	$2.0 MM
Total Exp	*$32.4 MM*

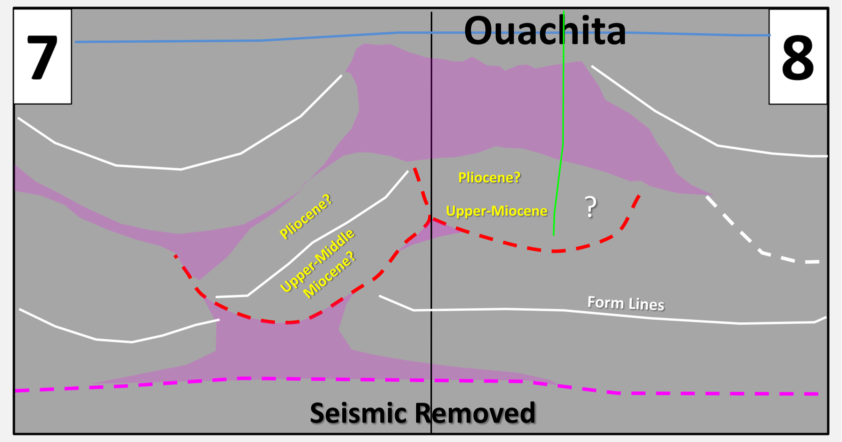




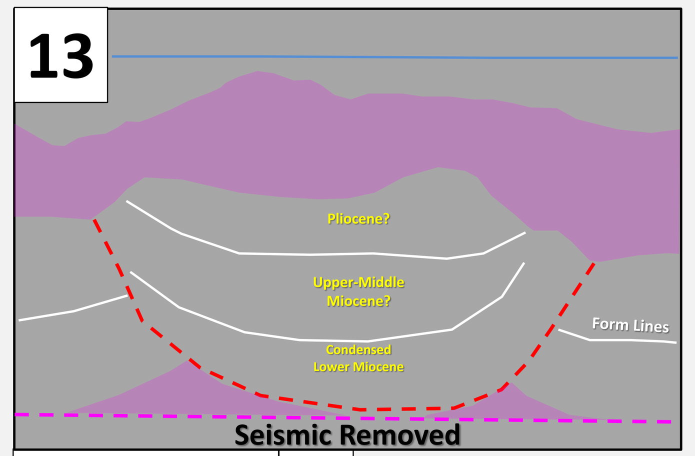


Interpretation similar to Hudec





Interpretation similar to Rowan and Inman (2011)



13 — Prospect – Sale 222

Total High:	$51 MM
Total $ Exposed	$74 MM

KC 426 – 2 Bids

XOM	**$15.1 MM**
Statoil	$6.2 MM
Total Exp	*$21.3 MM*

KC 427 – 2 Bids

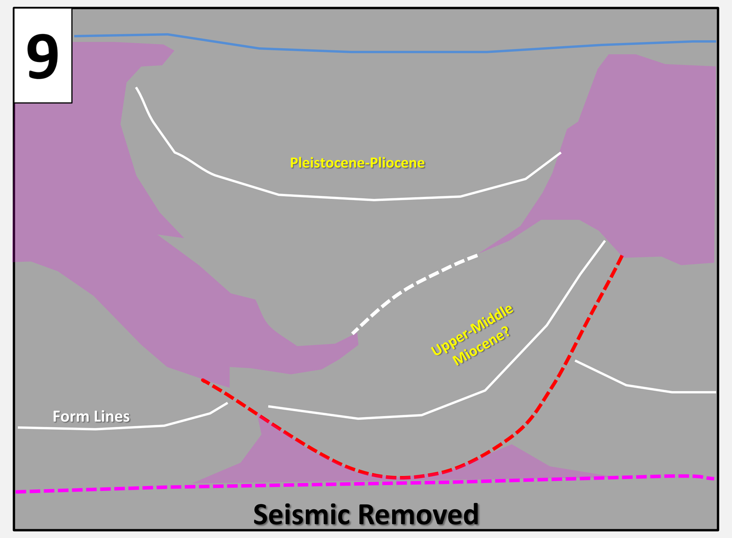
Statoil	**$6.3 MM**
XOM	$5.6 MM
Total Exp	*$11.9 MM*

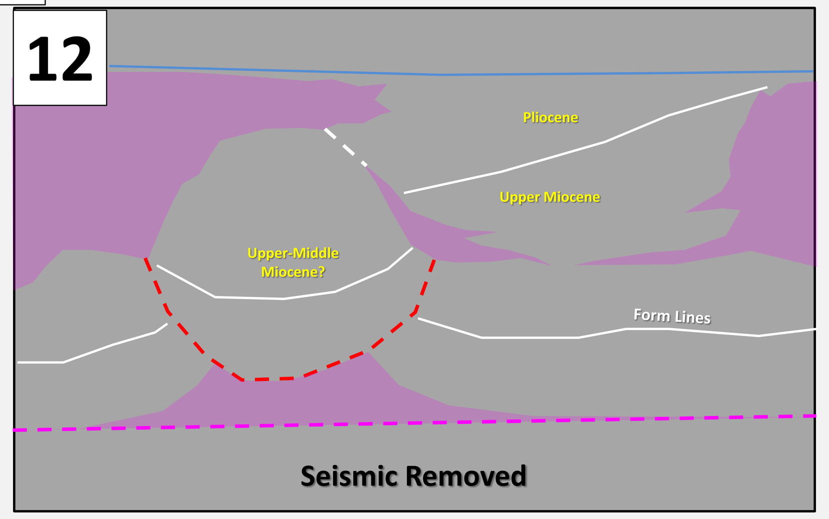
KC 470 – 2 Bids

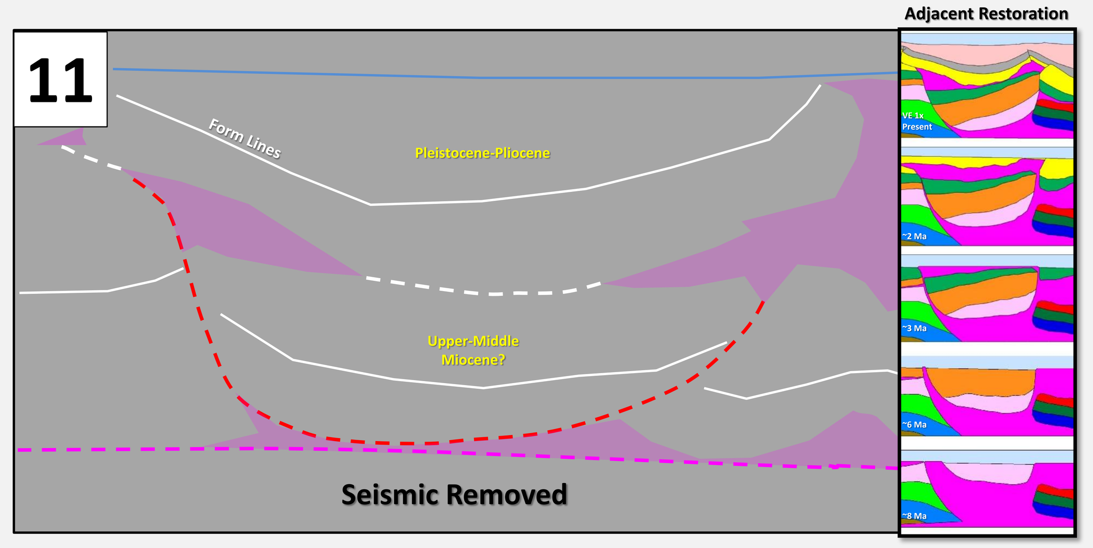
XOM	**$15.1 MM**
Statoil	$1 MM
Total Exp	*$16.1 MM*

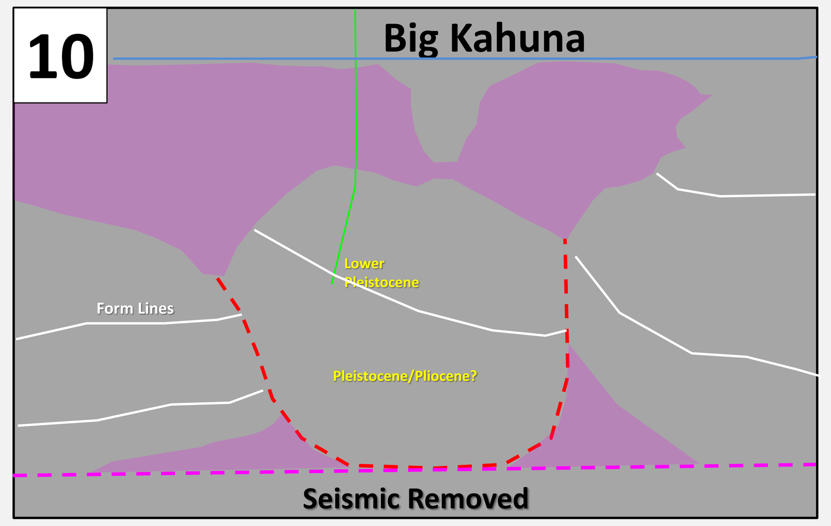
KC 383 – 2 Bids

Statoil	**$14.5 MM**
XOM	$10.1 MM
Total Exp	*$24.6 MM*









Encased Secondary Minibasins: an Emerging Play in the Deepwater Gulf of Mexico

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Global Exploration: Gulf of Mexico, Marathon Oil Company

Observations of Contrasting Basins

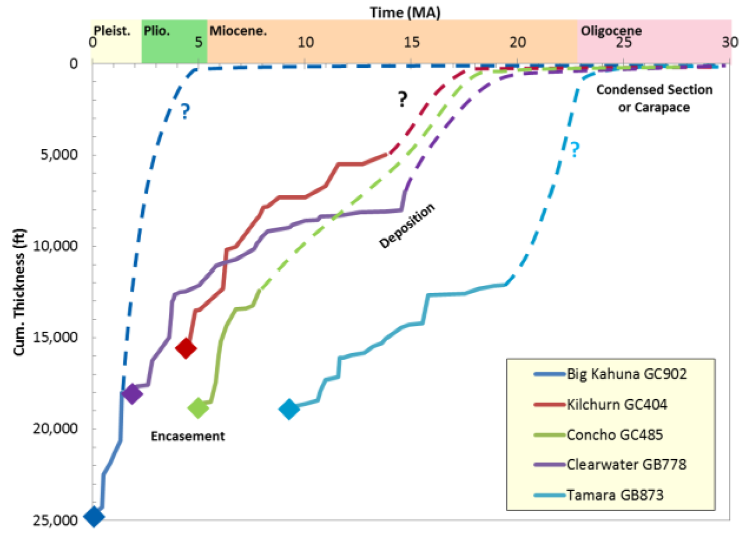
Big Kahuna Basin

- Asymmetric "bucket" basin
- Pleistocene-to-Pliocene(?) section
- High average deposition rate
- Late Pleistocene encasement
- ~12,000' thick present day canopy
- Salt flowed over the basin radially from multiple directions
- High relief (~6,000') unconformable encasement surface with prominent sutures
- Basin rotated ~20° after encasement
- Basin foundered >9,000' after encasement
- Basin foundered into a large vertical salt wall/feeder
- Bottom of basin is welded at Louann level

Kilchurn Basin

- Symmetric basin
- Pliocene-to-Lower Miocene section
- Moderate average deposition rate
- Early Pliocene encasement
- Over-riding canopy is largely welded
- Salt flowed over the basin predominantly from the North
- Very low relief and conformable encasement surface with subtle sutures
- Little rotation of basin after encasement
- No foundering after encasement
- Basin subsided over a small (leaning?) salt feeder
- Bottom of basin is welded onto primary basin section

Depositional History



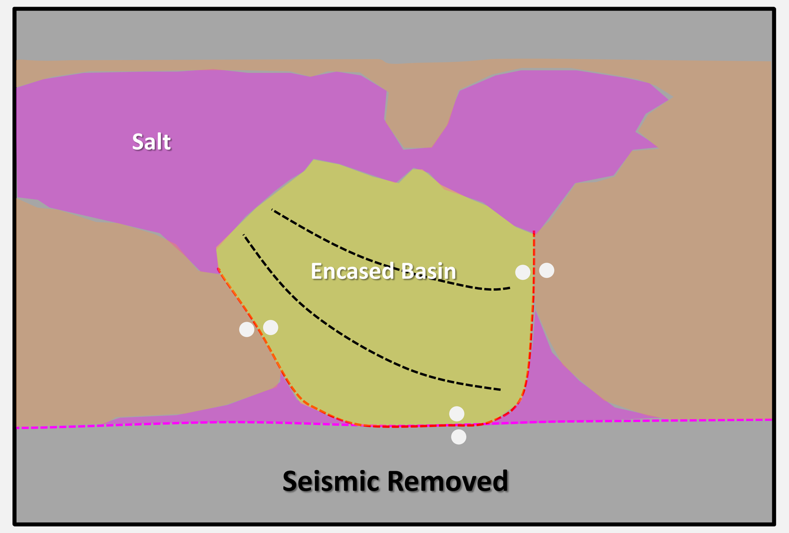
Encased Basin Characteristics

Basin	Age of basin fill	Age of basin encasement	Continued post-encasement subsidence?	Basin symmetry	Post-encasement basin tilt*	Subsided into/over diapir?	Basin size relative to diapir size	Stacked basin?
1 Tamara GB 871-1	Early Miocene (?) – Late Miocene	Late Miocene	yes(?)	unknown (poor image)	low (?)	yes	unknown (probably similar)	no
2 Clearwater GB 778-1	Mid Miocene – Early Pleistocene	Early Pleistocene	no	asymmetric	Very low	unknown (possibly not)	N/A	no
3 Concho GC 485-1	Mid Miocene(?) – Early Pliocene	Early Pliocene	no	symmetric	very low	possibly	unknown (possibly larger)	no
4 Kilchurn GC 401-1, ST-1	Mid Miocene – Early Pliocene	Mid Pliocene	no	symmetric	very low	possibly	unknown (possibly larger)	no
5 Angel Fire	Mid Miocene – Late Miocene	Latest Miocene (?)	yes	symmetric	low	partially (?)	larger	no
6	Late Miocene (?)	Latest Miocene (?)	yes(?)	symmetric(?)	moderate(?)	yes	similar	yes
7	Mid Miocene – Late Miocene	Latest Miocene (?)	yes	asymmetric	moderate	yes	larger(?)	yes
8 Ouachita GC 376-1BP3	Late Miocene	Latest Miocene	yes	unknown (poor image)	high	possibly	unknown (poor image)	no
9	Mid Miocene – Early Pliocene (?)	Latest Miocene – Early Pliocene (?)	yes	asymmetric	moderate	yes	similar	yes
10 Big Kahuna GC 902-1	Pliocene (?) – Late Pleistocene	Late Pleistocene	yes	asymmetric	low	yes	similar width but not length	no
11	Mid Miocene – Late Miocene/Early Pliocene (?)	Latest Miocene – Early Pliocene (?)	yes	symmetric(?)	low	yes	similar	yes
12	Mid Miocene – Late Miocene	Late Miocene	yes	symmetric	low	yes	similar	yes
13	Mid Miocene –Pliocene	Late Pliocene (?)	no	symmetric	low	yes	similar	no

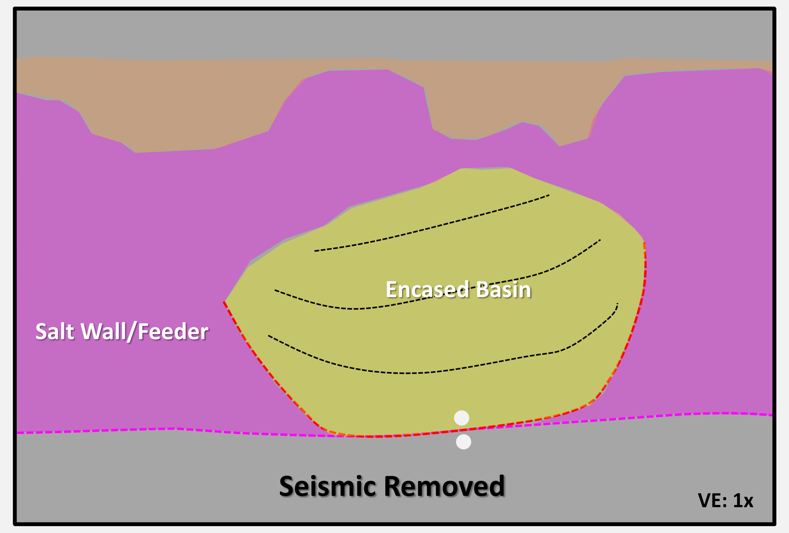
* Basin tilt defined as Low 0° - 30°; Moderate >30° - 60°; High >60°

Big Kahuna Basin

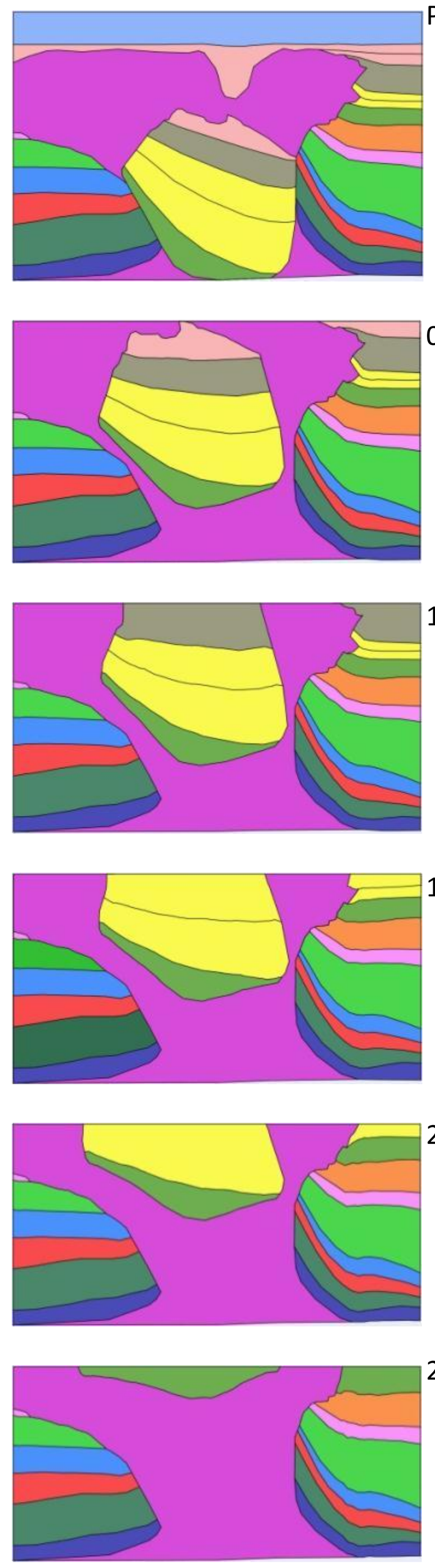
Dip Section



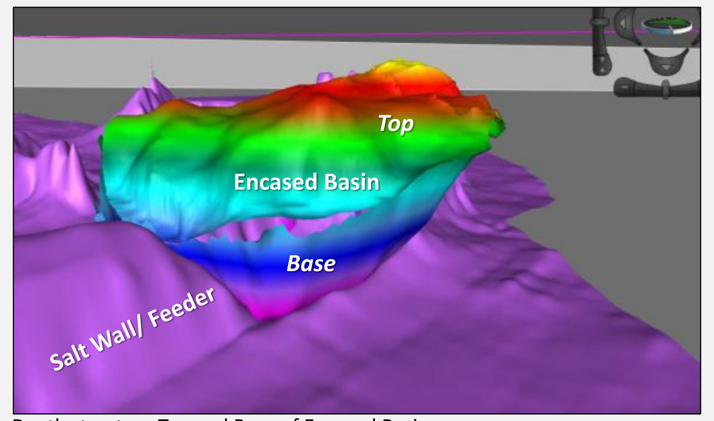
Strike Section



Reconstruction

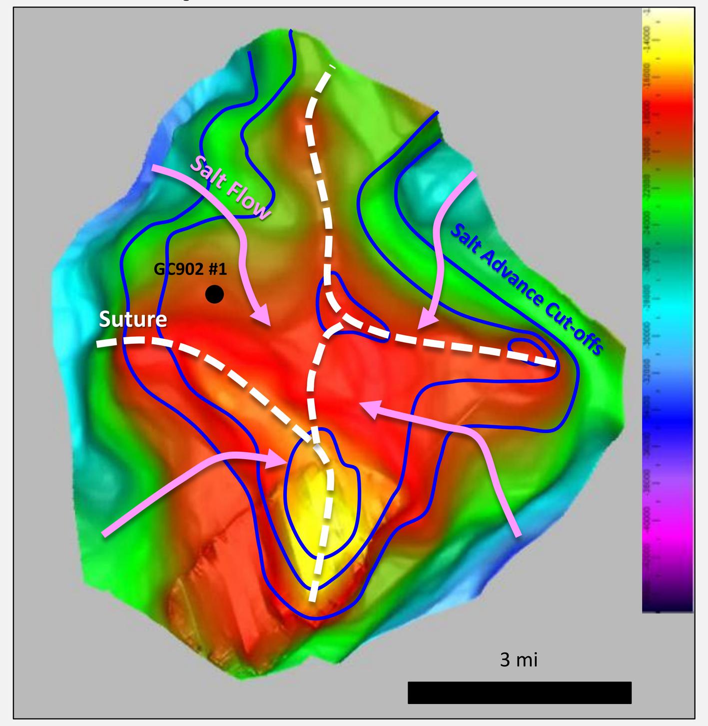


3D View

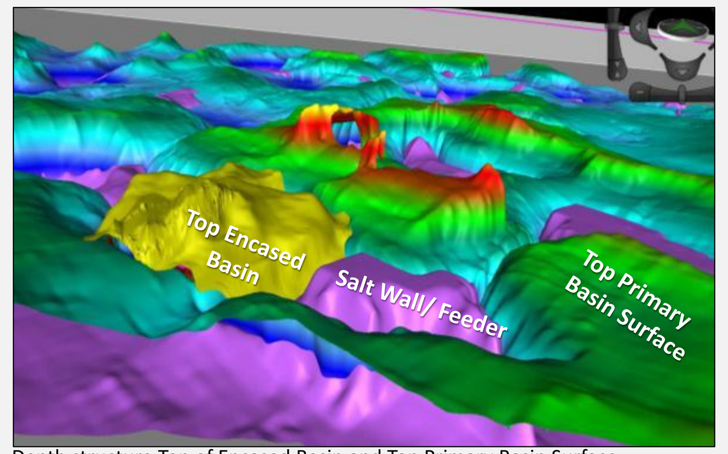


Depth structure Top and Base of Encased Basin

Top of Basin/Base of Salt



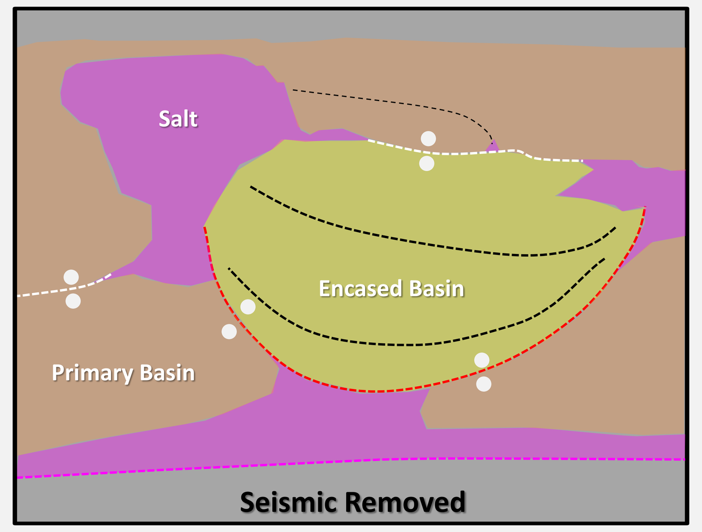
Regional Setting – 3D View



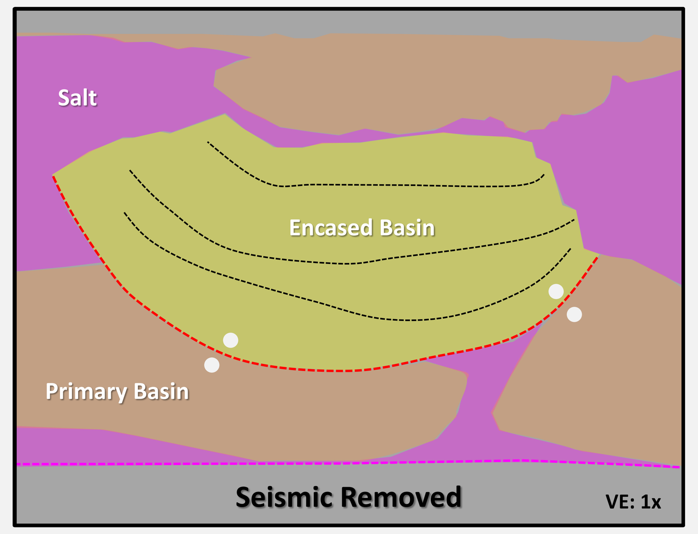
Depth structure Top of Encased Basin and Top Primary Basin Surface

Kilchurn Basin

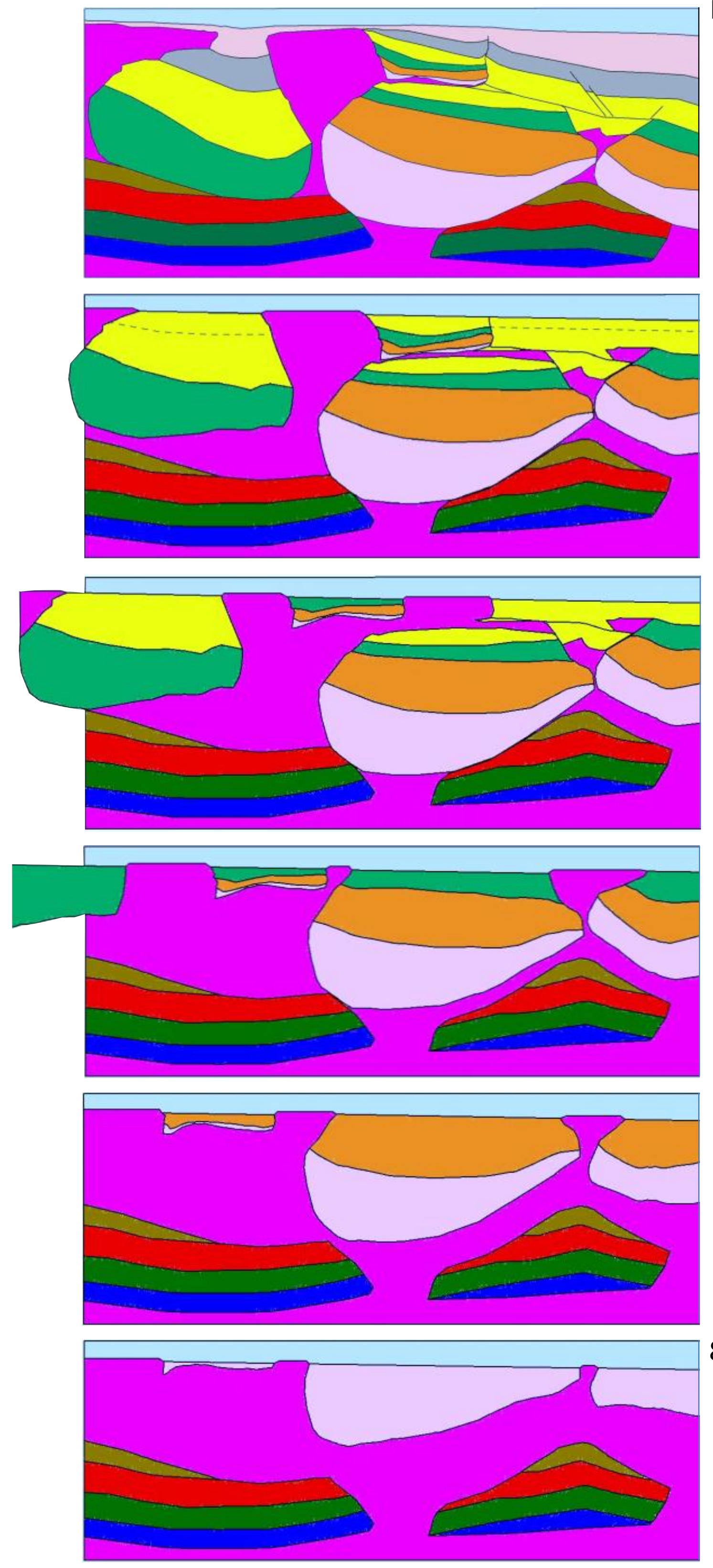
Dip Section



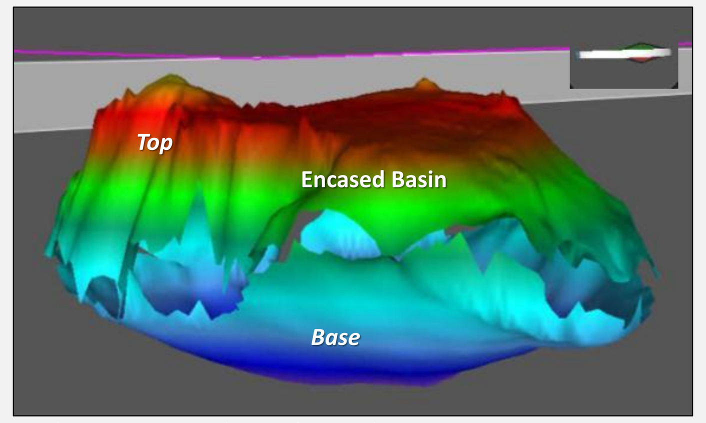
Strike Section



Reconstruction



3D View



Depth structure Top and Base of Encased Basin

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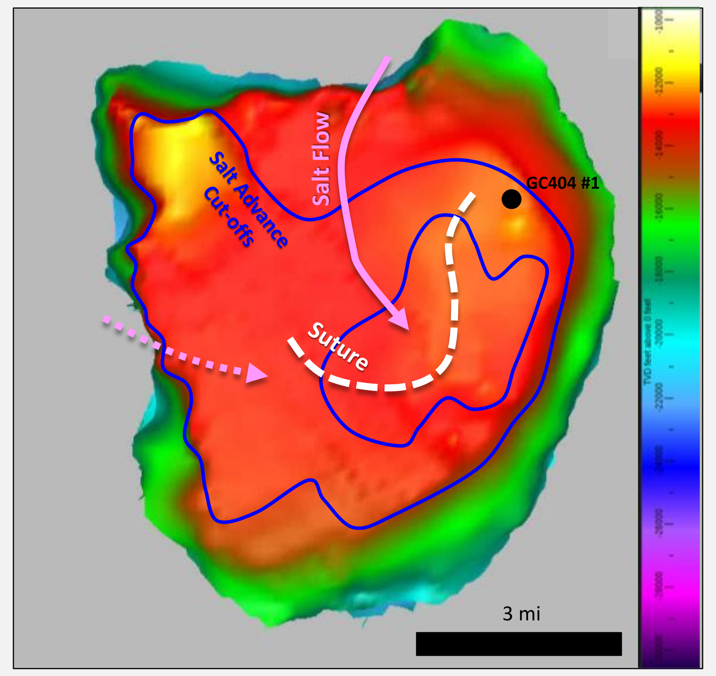
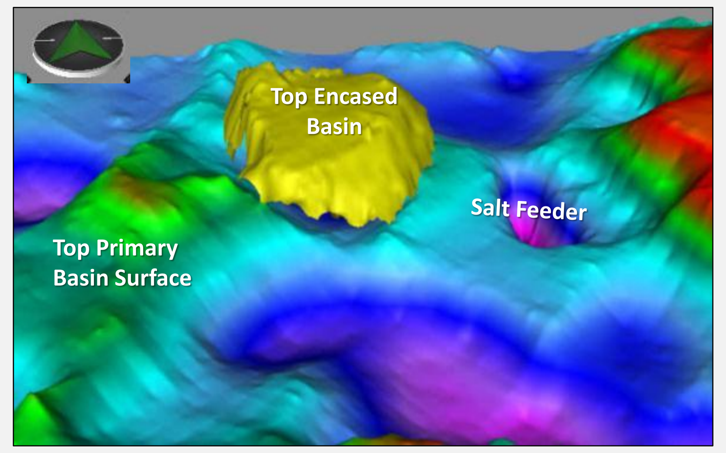


Regional Setting – 3D View



Depth structure Top of Encased Basin and Top Primary Basin Surface

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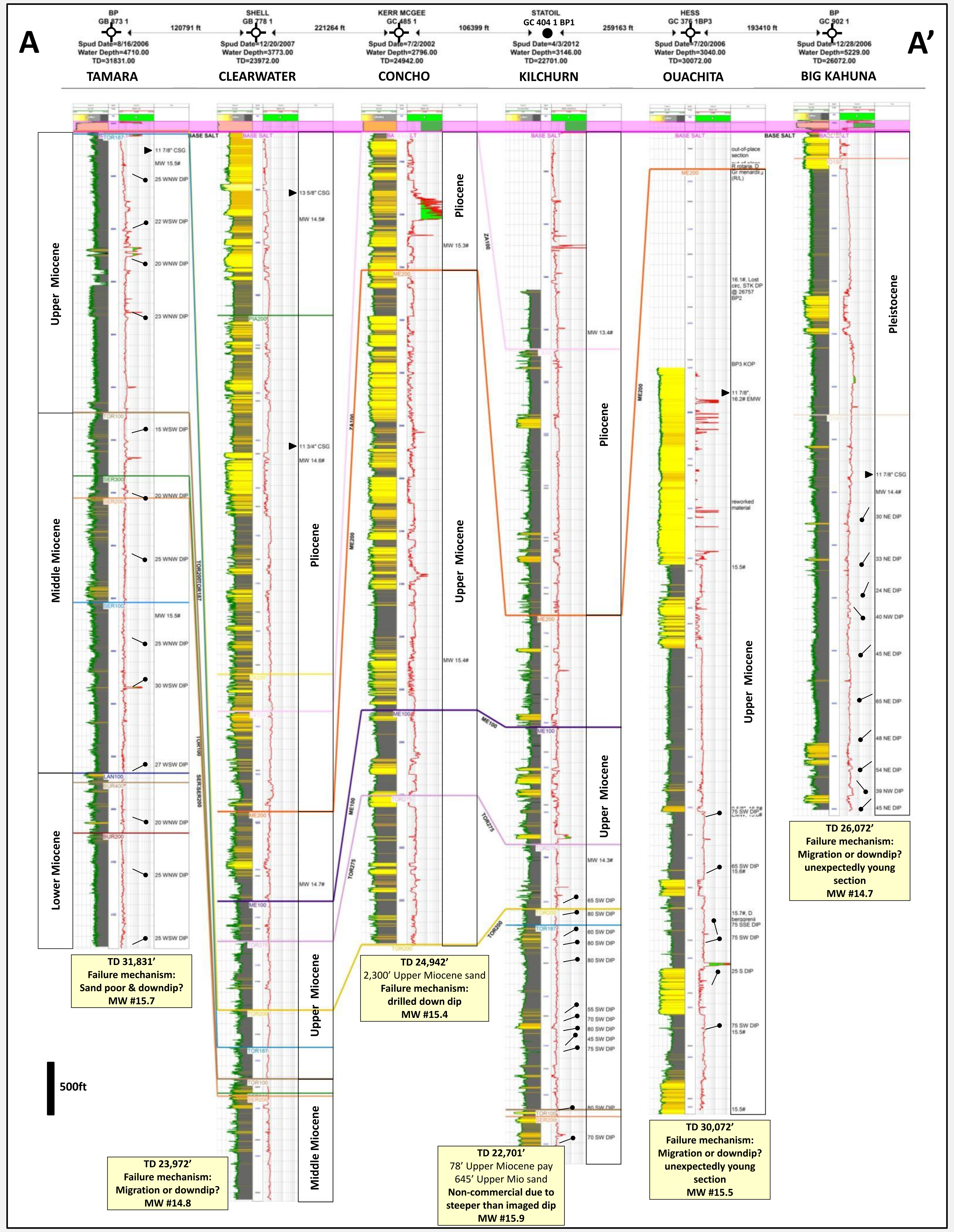
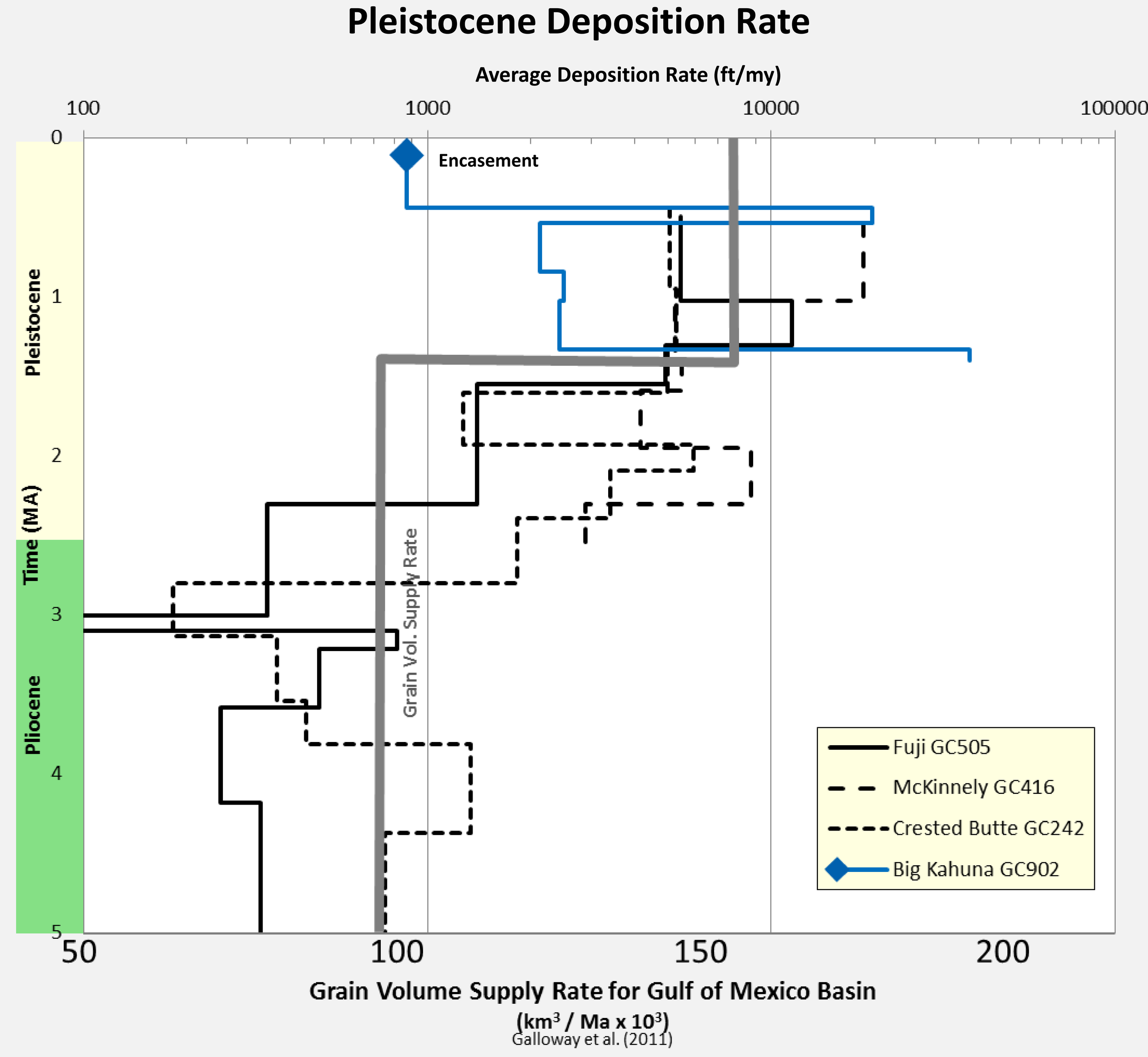
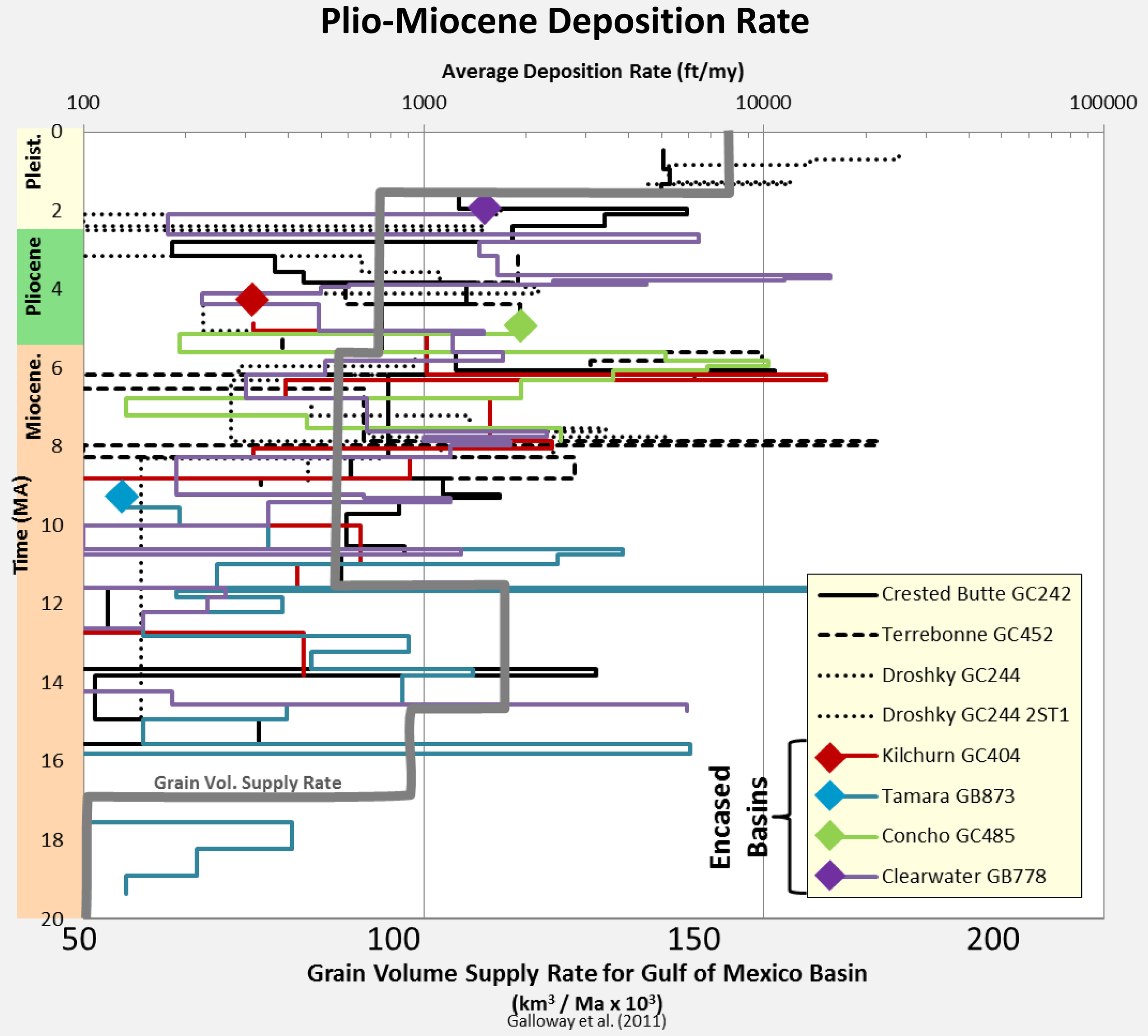
Encased Basin Penetrations & Deposition







Advances in Imaging of Encased Basins

Seismic Imaging

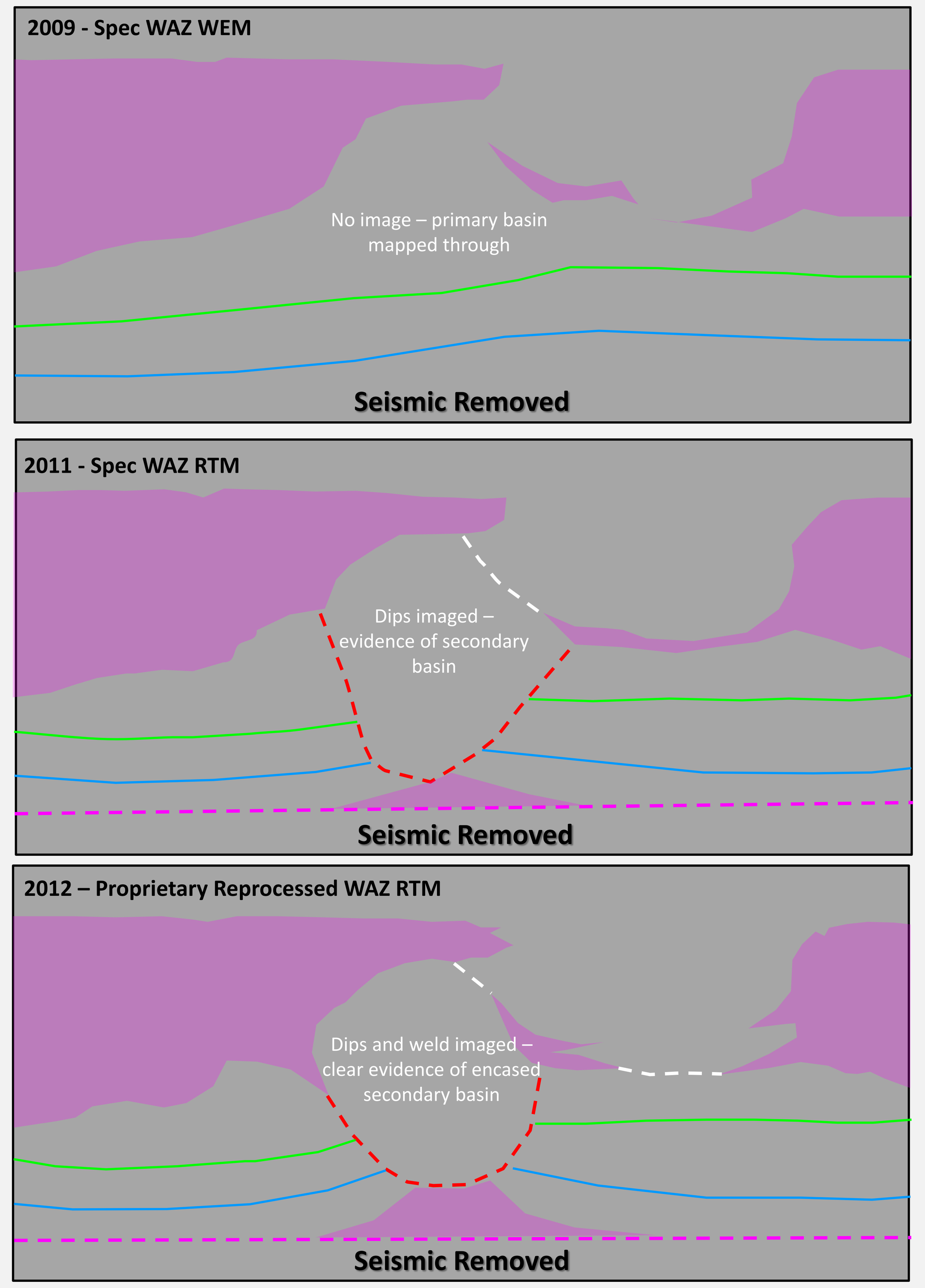
Recent advances in seismic acquisition and processing have resulted in the imaging of previously unseen secondary encased basins. These include:

Acquisition: Wide azimuth (WAZ), full azimuth (FAZ), and long offset

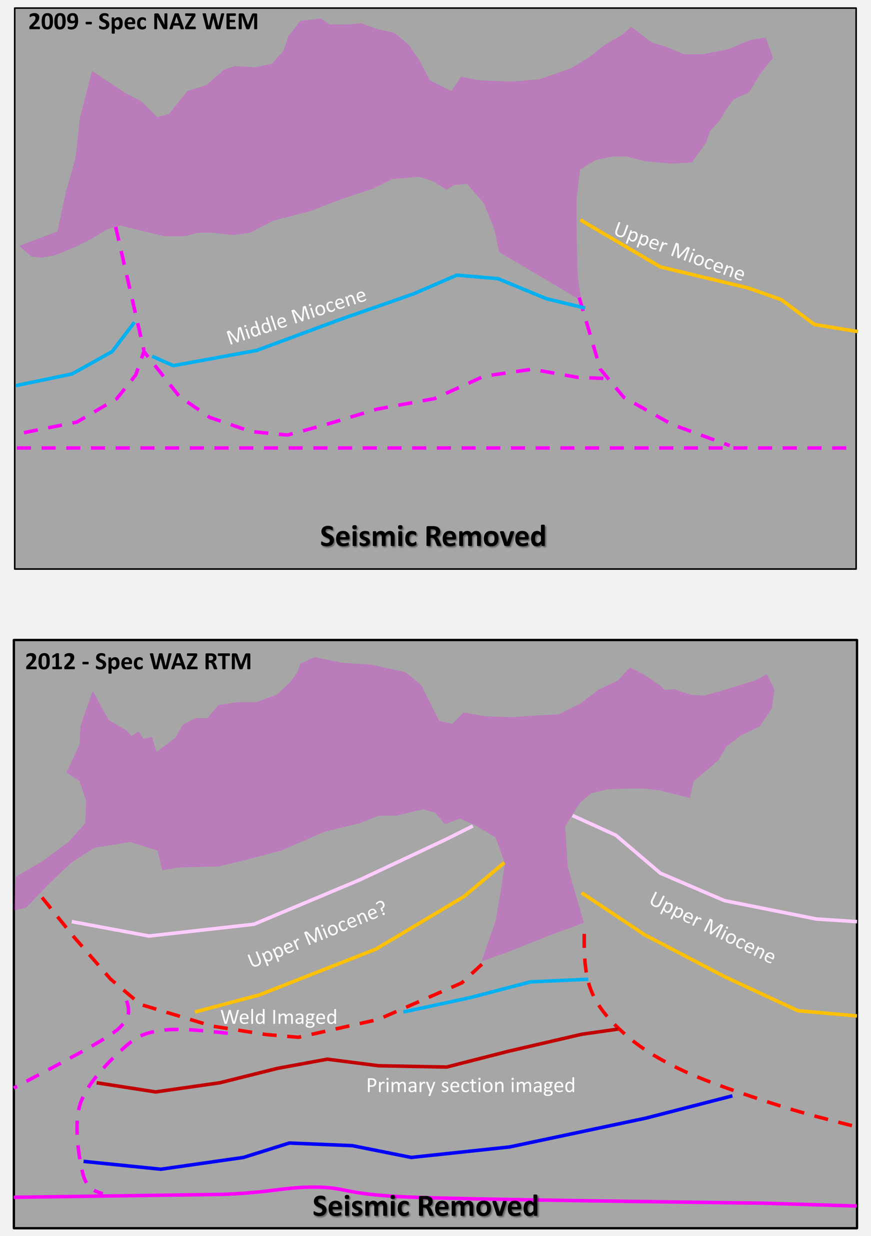
Processing: Reverse Time Migration (RTM), Full Waveform Inversion (FWI), handling anisotropy through Tilted Transverse Isotropy (TTI), and Surface Related Multiple Elimination (3D SRME)

With the knowledge of their presence and widespread distribution, we are developing our understanding of the processes by which encased basins form, and the character of the sediments within them. This allows us to build geologic models to better predict velocities and further enhance imaging.

Evolution of Seismic Image – Walker Ridge Example



Evolution of Seismic Image - Green Canyon Example



Observations

- Penetrated sections have a wide range of reservoir content (compare >2,300' of sand in Concho to functionally no sand at Tamara)
- With the exception of the Big Kahuna basin, most encased basins appear to have been deposited during the Miocene and were prone to encasement during the Late Miocene to Early Pleistocene
- Prior to and during encasement, the deposition rate within encased basins was comparable to the range in other nearby basins that were not encased
- No indication that encasement was due to a regional decrease in deposition rate
  - Big Kahuna, Kilchurn, and Tamara well data indicate deposition rates on the low end of the range of non-encased offset wells
  - Conversely, Clearwater and Concho well data indicate deposition rates on the high end of the range of non-encased offset wells
- Encasement was not always associated with a local decrease in deposition rate
  - Big Kahuna, Kilchurn, and Tamara well data indicate a reduction in deposition rate just prior to encasement
  - Clearwater and Concho well data indicate an increase in deposition rate prior to encasement. For these basins, local salt tectonics may have been a larger controlling factor than deposition

Conclusions

Encased basins of Miocene-to-Pleistocene age in the Gulf of Mexico are being recognized more frequently due to advances in seismic acquisition and processing. Incorporation of the proper velocities of encased basins into velocity models may improve the depth imaging of the surrounding primary section exploration targets, as well as targets within the encased basins themselves. Well penetrations of encased basins are relatively few; most were drilled prior to imaging advancements and were not optimally positioned to test the basins' prospectivity. The wells encountered a wide range of outcomes including unexpectedly young section, steep dips, a range of lithologies. Encased basins exhibit a large variation in geometries, symmetry, weld characteristics, amount of post-encasement foundering and tilting, and relative timing of encasement versus foundering. The factors controlling whether a minibasin is likely to become encased are complex. Examination of sedimentation rate of encased and nearby non-encased secondary basins of similar age do not show large differences, indicating that local factors such as salt budget, proximity to a diapir or another secondary basin, and the relative sizes of the minibasin to the salt feature into which it sinks, have a strong control on encasement. As recent leasing activity indicates, encased basins are an emerging play type in the Gulf of Mexico and elsewhere in the world.

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Data Use and Permissions

Public Data:

- NOAA bathymetry map
- Well logs: GB873-1, GB778-1, GC485-1, GC376-1, GC902-1

Permissions:

- GC404-1 logs from Statoil
- AAPG figure for one-time use

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