Note: removed confidential, sensitive data from presentation

Cook Inlet Exploration: Past, Present, Future

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Abstract

Cook Inlet Exploration: Past, Present, and Future

By D. Buthman

AGS Talk 3/17/2020 at BP Energy Center, Anchorage

The first commercial oil or gas discovery in the Cook Inlet Basin occurred in 1957 at Swanson River Field, located on the Kenai Peninsula. After discovery, a number of exploratory wells were drilled in the Cook Inlet targeting oil, but found large amounts of gas. Monetizing the gas via the Fertilizer and LNG Plants spanned several decades, but eventually the excess supply was burned off. During these early drilling campaigns, approximately 1.8 billion barrels of oil and over 7 trillion cubic feet of gas were found.

Past exploration efforts depended on locating oil seeps, mapping surface geology, and acquiring both potential fields data, seismic, and ultimately drilling wells. In 2000, when the supply of gas in the Inlet started running low, Union and Marathon started exploring specifically for gas, and discovered Ninilchik Field, as well as several other gas fields in the ensuing years. The methods employed for these discoveries relied on 2D seismic, potential fields, and surface geologic fieldwork—however, these discoveries were made only after drilling a number of dry holes that ultimately highlighted the shortcomings of each individual technique.

Presently, Hilcorp Alaska LLC is exploring the Cook Inlet Basin for, primarily, gas, but when prospective traps are suspected the initial exploration wells are taken deep enough to evaluate the oil potential. We've modernized our exploration toolbox, have acquired additional surveys, and are integrating all data into consistent, velocity-corrected, interpretations. Our recent Seaview Discovery at Anchor Point is evidence of this perseverance.

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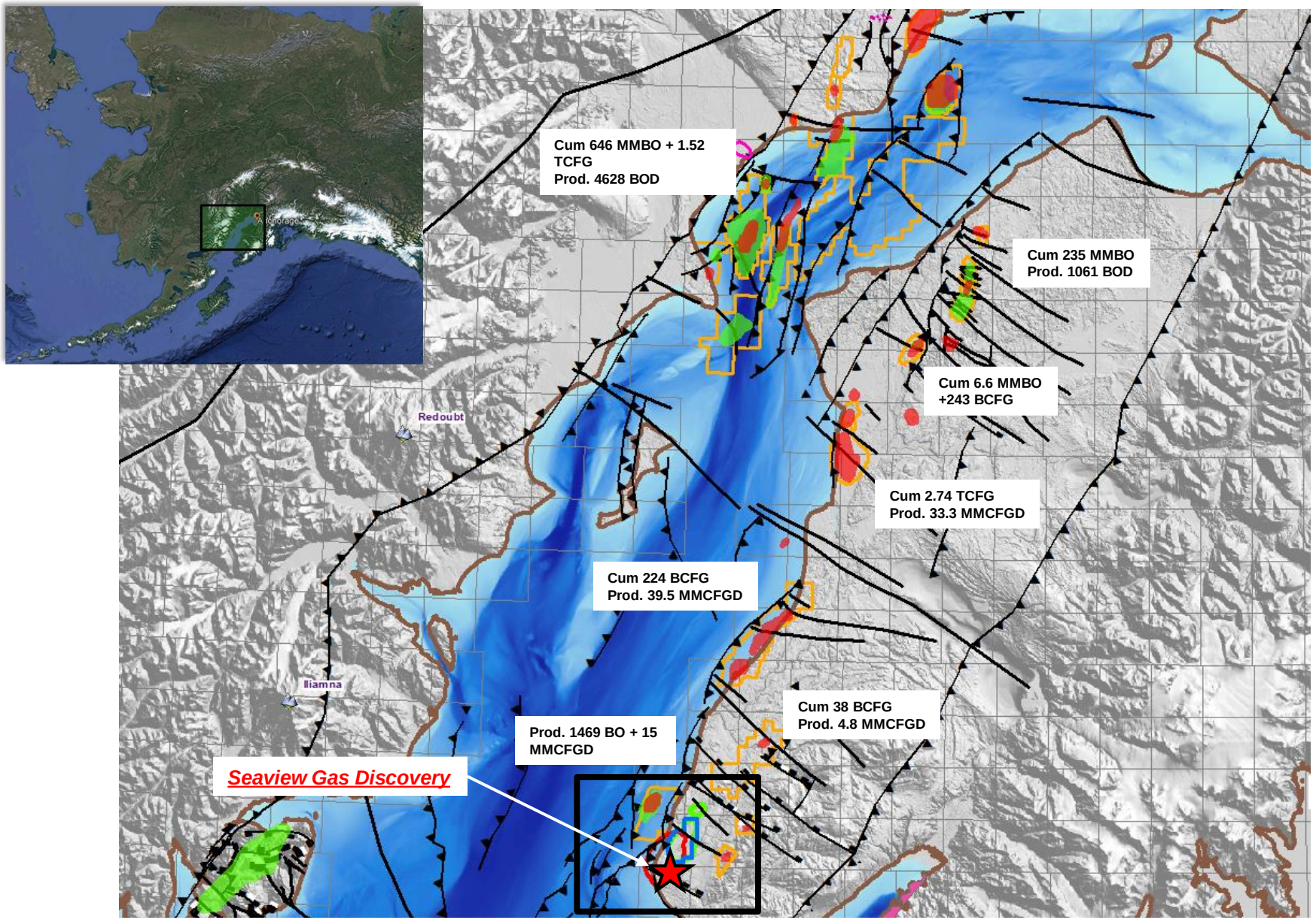
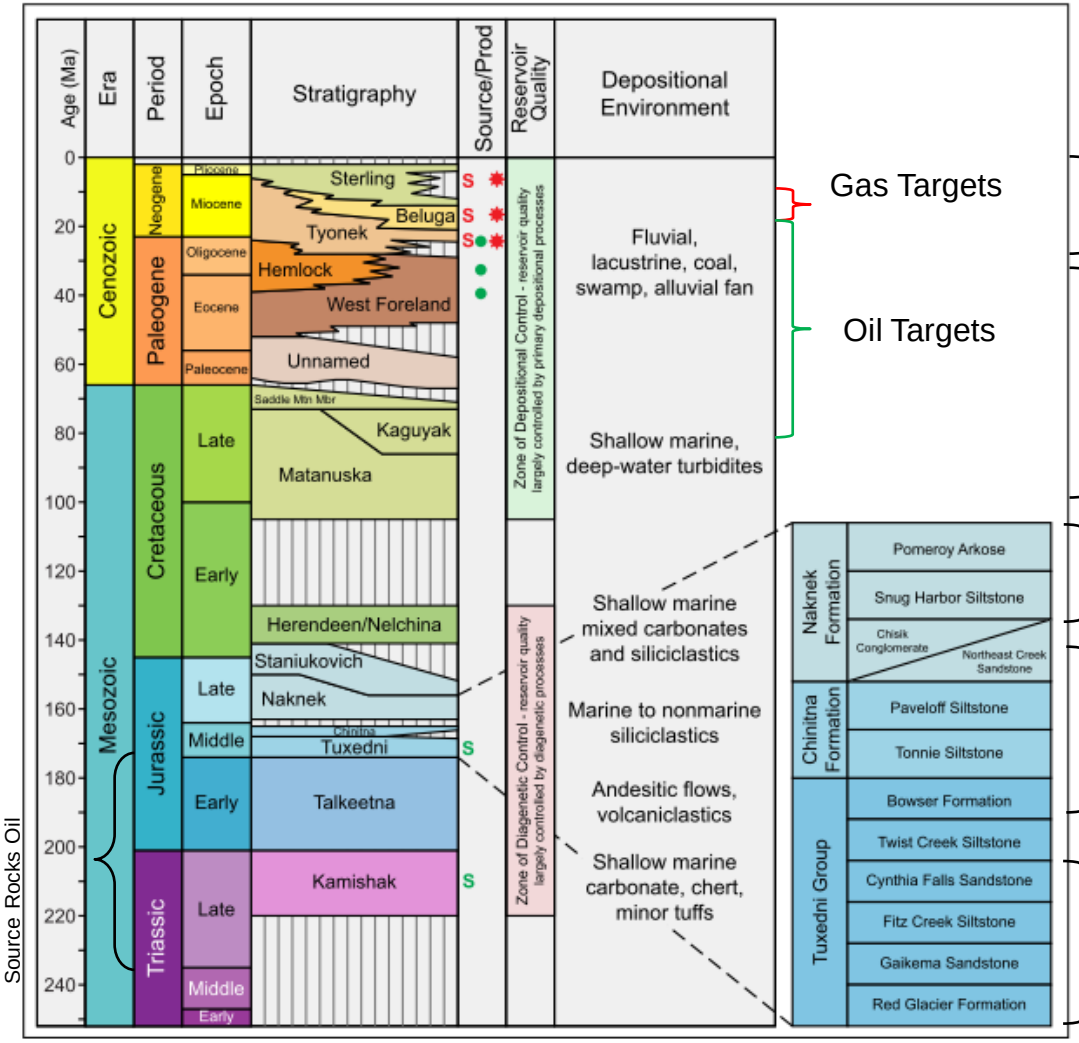
Regional Location Map 2019



Stratigraphic Column



Key Outcrops:

Gas Targets

Oil Targets

Ninilchik Bluffs
Diamond Gulch
Seldovia

Wishbone Hill

Bear Mtn Lodge

Chisik Island

Fossil Point

Modified from Report of Investigations 2012-1, DGGS, LePain, Lillis, Helmold, Stanley.

PAST EXPLORATION

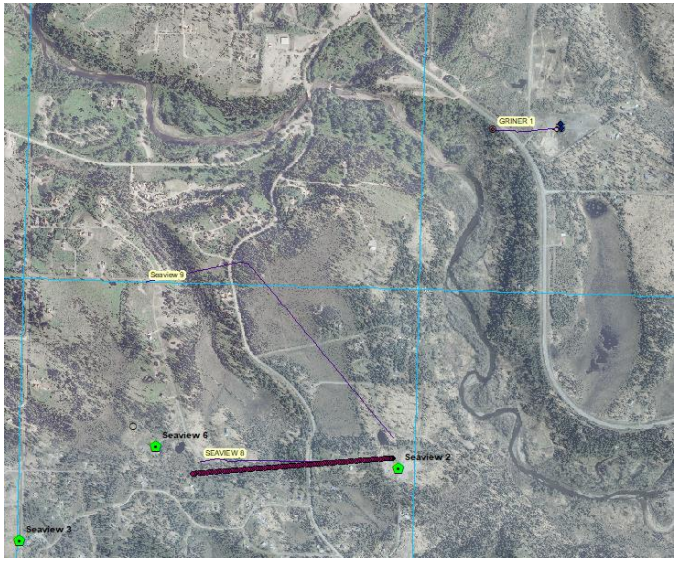
Exploration Methodologies Employed

- Surface Geology, Seeps
- Gravity
- Magnetics
- Seismic
- Subsurface Wells

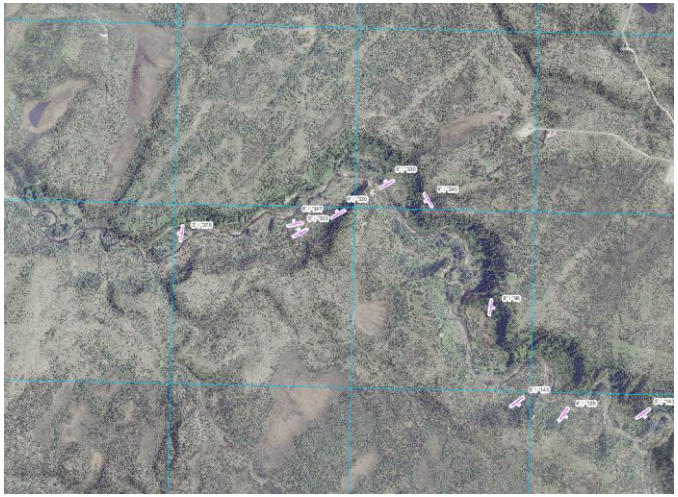
Surface Geology (Trap) & Oil Seeps (Source)

Surface Geology: Faults

Surface Geology: Drainage Anomalies



Seaview nosing drainage anomaly.



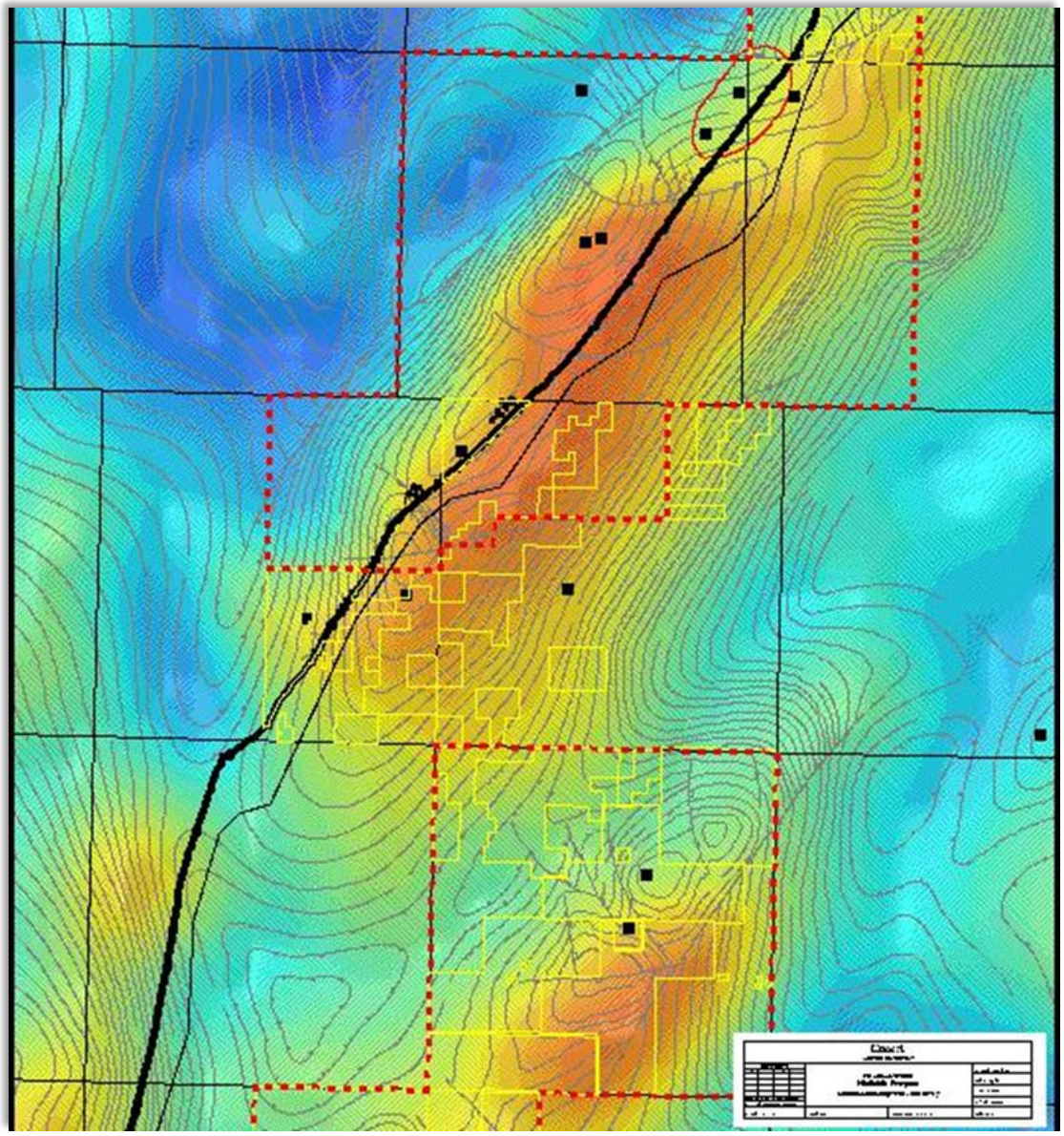
Happy Valley type nosing drainage anomaly.

Swanson River circular drainage anomaly around Soldotna Creek Field

Gravity

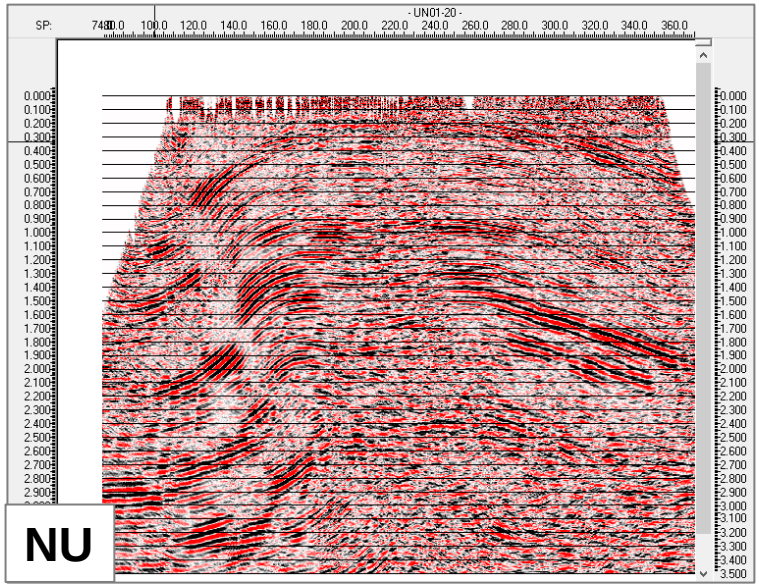
PAST:
UCL 2000 Ninilchik Prospect:

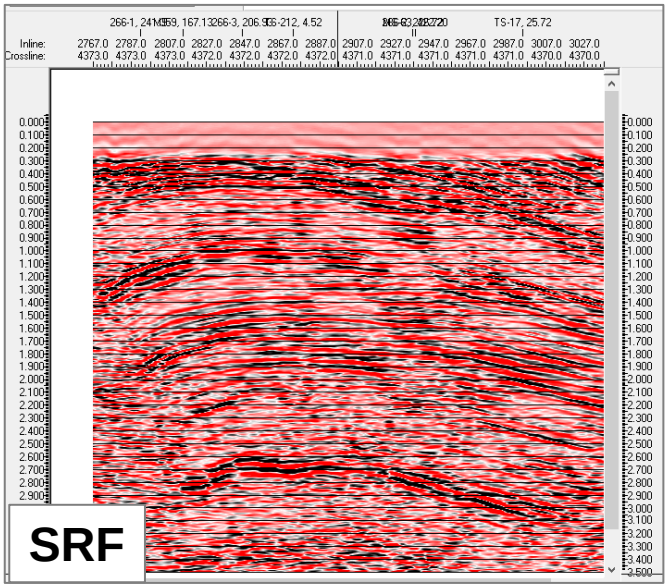
Bouguer gravity UC 5000' Legacy dataset land-marine merge and Top Tyonek Structure map.

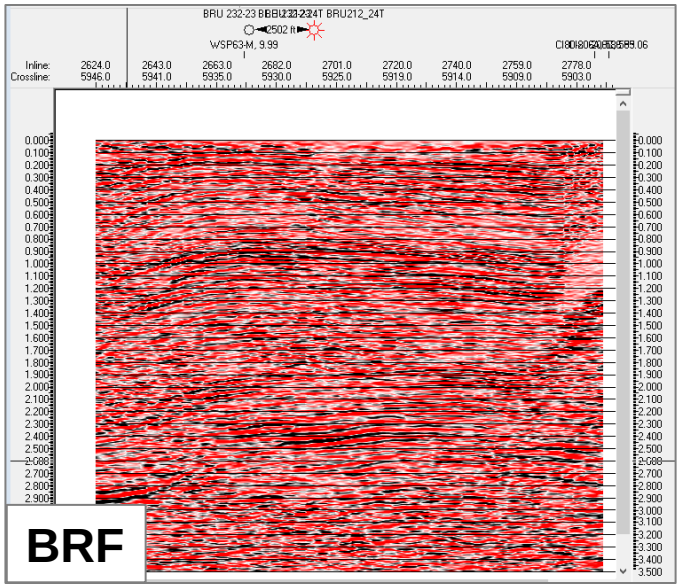


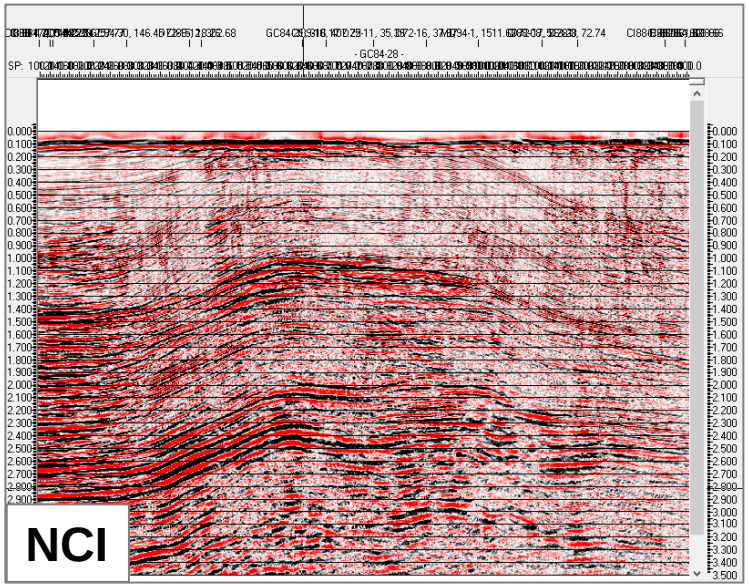
6 miles

Seismic Velocity Pitfalls Cook Inlet



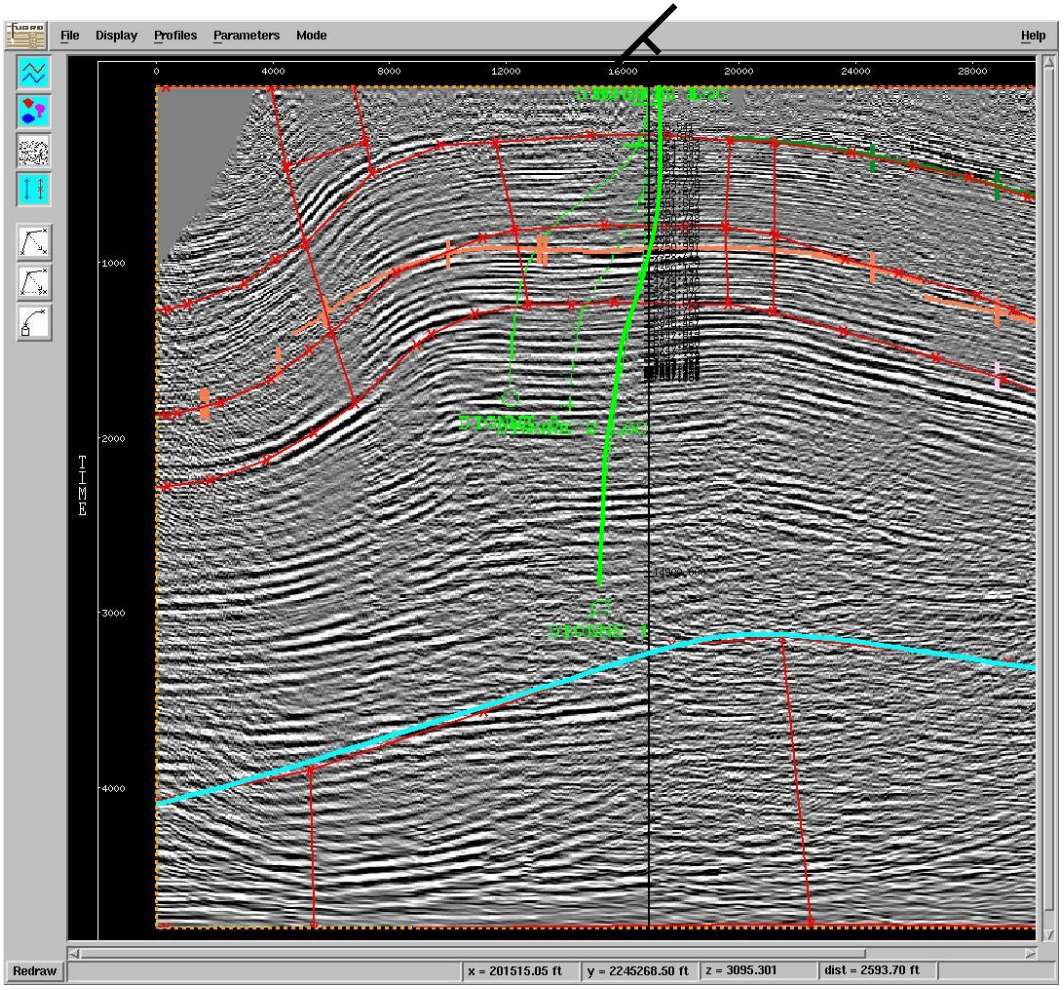






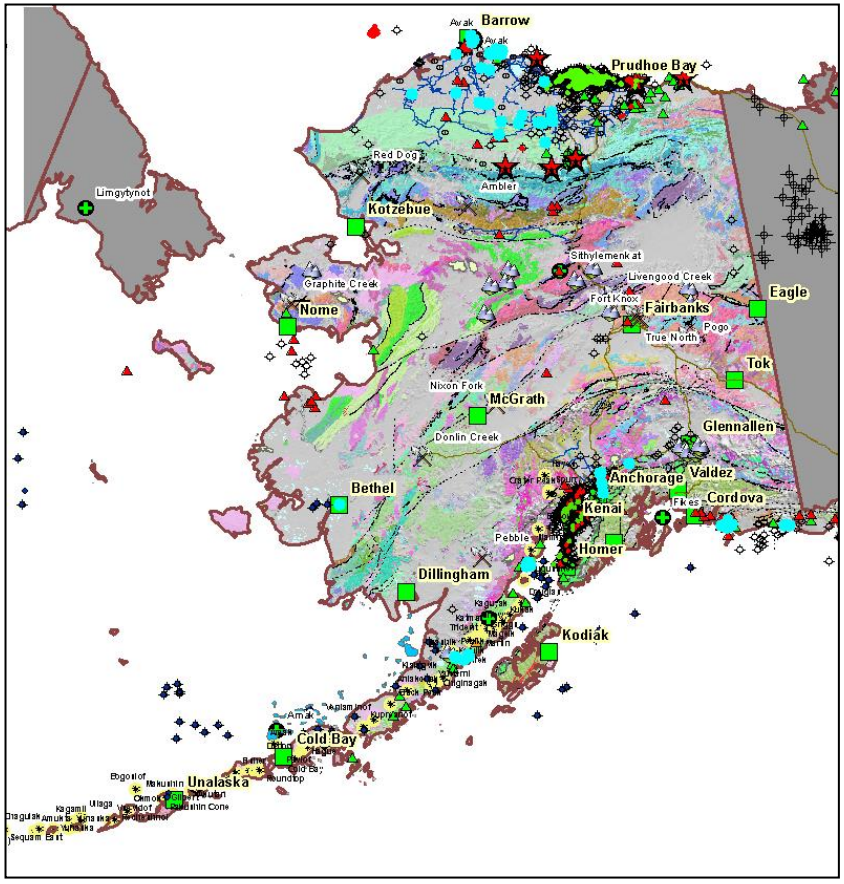
Note: some are shallow-induced gas sags, others aren't. Solution of inverting gravity to density to velocity helps accurately reprocess seismic data in depth.

Seismic Velocity Pitfalls

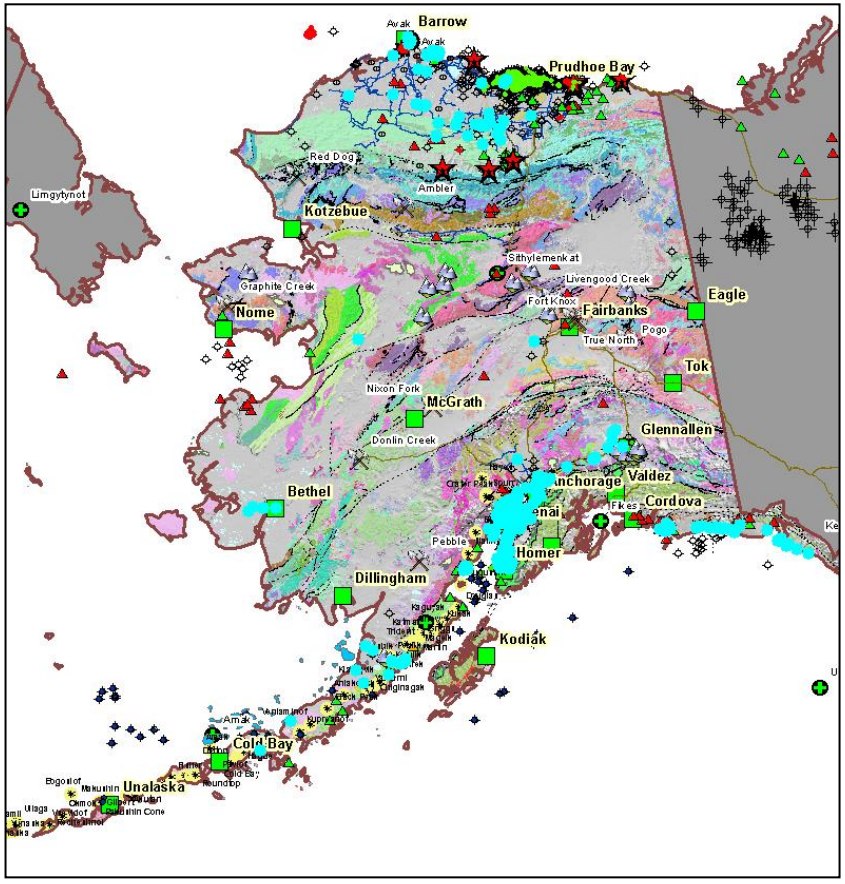


How could you possibly miss this large gas field with market and good gas price?

Drill Wells



Wells drilled prior to Bear Creek / Swanson River Field discoveries (1901-1956: 166 wells drilled total)



Wells drilled prior to Prudhoe Bay discovery (1901-1967: 567 wells drilled total).

Cook Inlet Oil & Gas History

1957-1970's: Exploration, Discovery, Development

- Swanson River Field discovered 1957, Statehood follows in 1958
- 7+ TCF of gas and 1.8 BBbls of oil are found during the search for oil in the late 1950's and early 1960's.
- Enstar completes pipeline in 1962 to transport gas from Kenai Gas Field to Anchorage.
- The Union Collier Chemical Plant (fertilizer plant) was completed in 1968, and the LNG plant was completed in 1969.
- The 60's were a decade of exploration, discovery, and infrastructure development in the basin, much of it devoted to monetizing gas discoveries. Companies shifted their exploration focus to the North Slope in the following decade

1980's-90's: Recession & Recovery

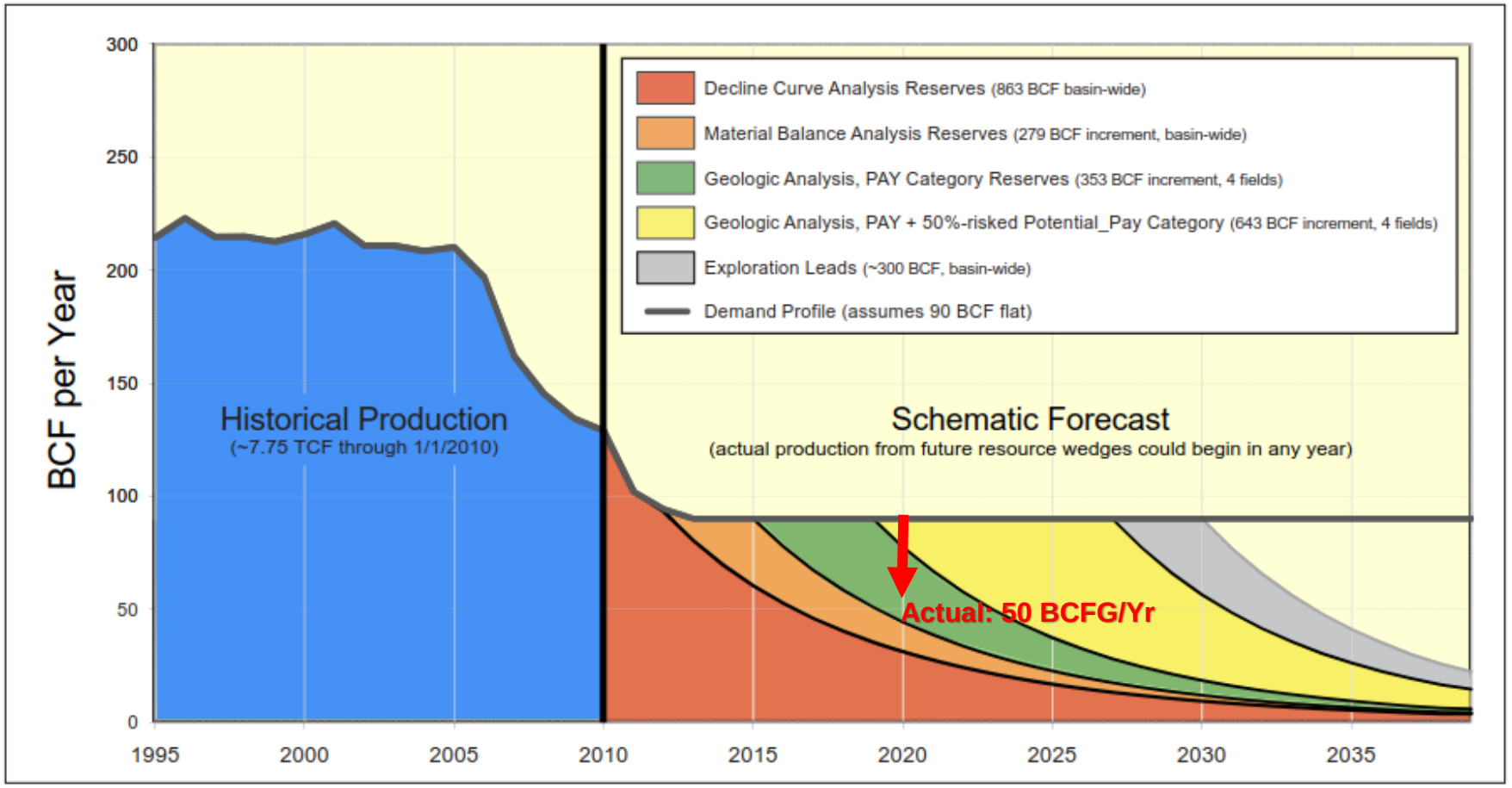
- The US average price of a barrel of oil drops from $44 to $12 from 1982 to 1986.
- The Permanent Fund Corporation was founded in 1980
- The major oil companies (Amoco, Shell) start exiting the Cook Inlet Basin
- The state starts area wide leasing program. In the late 90's, with legacy gas reserves declining, companies slowly began exploring the basin once again.
- Marathon and Unocal consolidate their positions and start acquiring large land positions

2000's-10's: Resurgence, Acquisitions, Market Stabilization

- 2000: Unocal signs long term contract with Enstar in November 2000, partners with Marathon, and together they discover Ninilchik Gas Field in late 2000
- The price of gas starts to rise, from $1.53 in 2000, to $7.26 in 2009, to $7.31 in 2018. This price increase and the decline in production pinches profitability for the LNG and fertilizer plants
- Unocal sells the fertilizer plant to Agrium in 2000, but shuts down in 2006 due to low supplies / high prices.
- LNG plant shuts down in 2015.
- 2012-date: Hilcorp purchases Chevron (Unocal's) and Marathon's interests in the Cook Inlet; drills 12 exploratory wells (all classifications); performs ~100 well workovers and drills 75 new development wells.

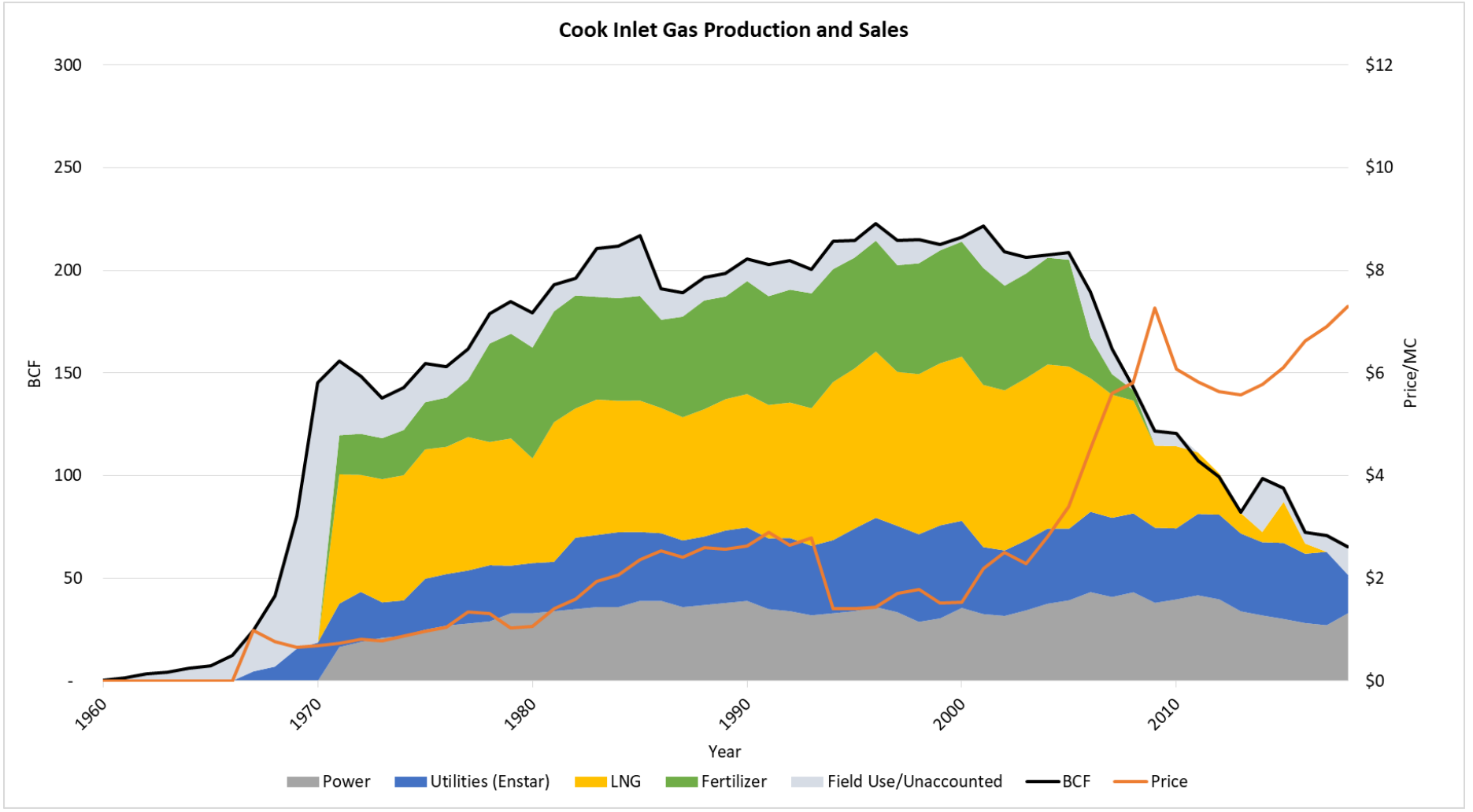
Gas Supply & Demand

Cum: 1.378 BBblO + 7.5 TCFG

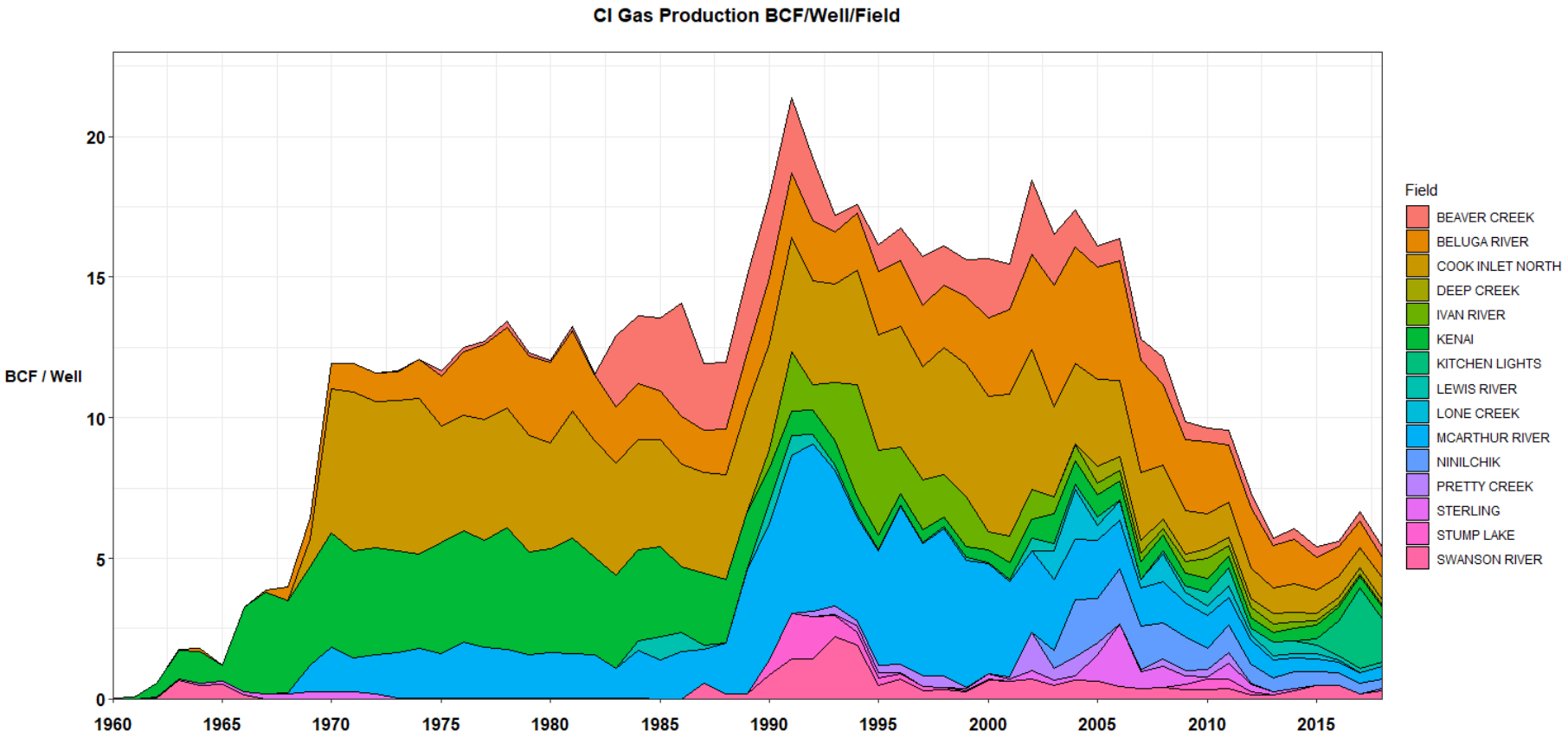


Hartz, J.D., Kremer, M.C., Krouskop, D.L., Silliphant, L.J., Houle, J.A., Anderson P.C., and LePain, D.L., 2009, Decker, P.L., ed., Preliminary engineering and geological evaluation of remaining Cook Inlet gas reserves: Alaska Division of Oil and Gas report, 37 p., available online at: http://www.dog.dnr.state.ak.us/oil/

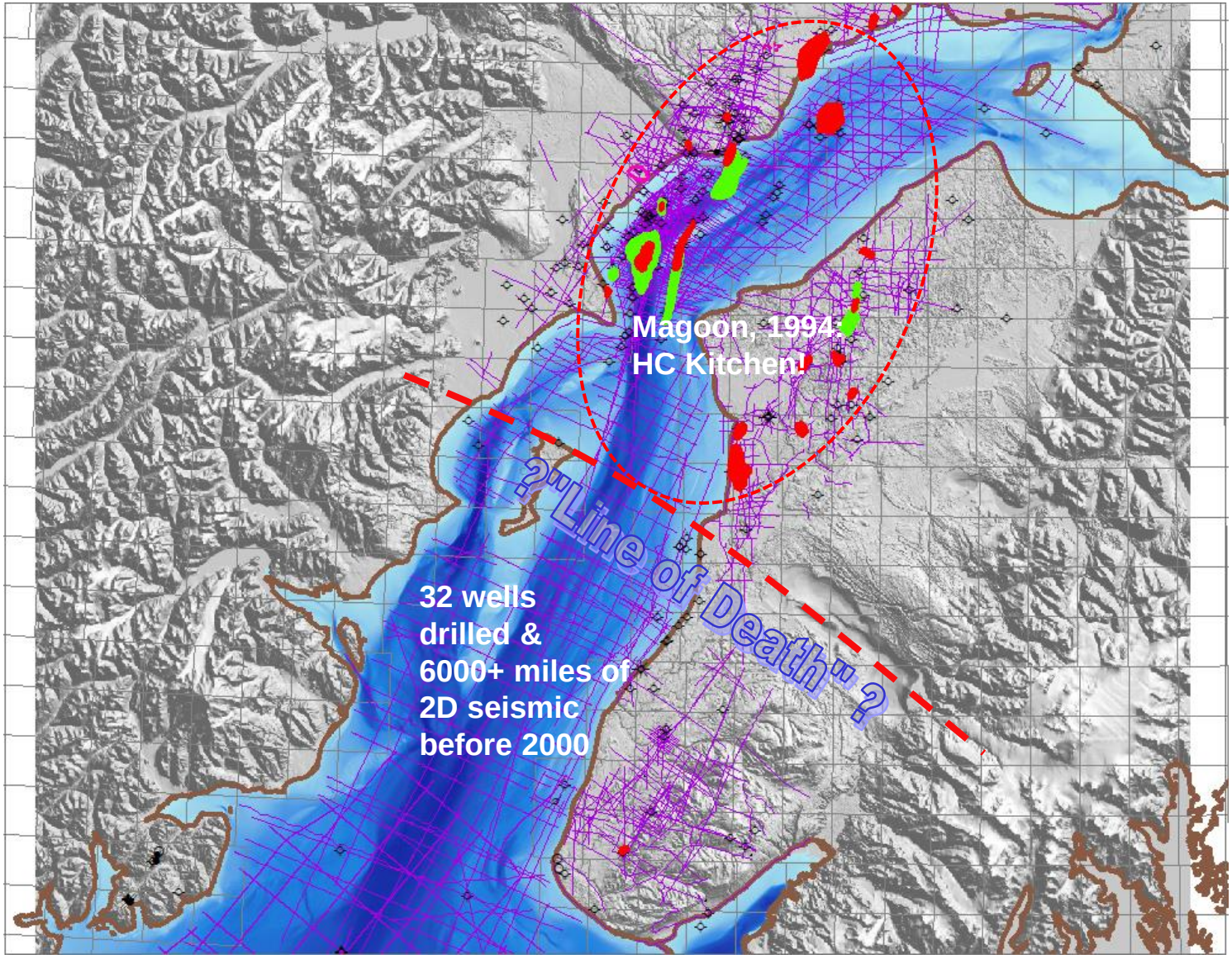
Cook Inlet Gas Historical Graph



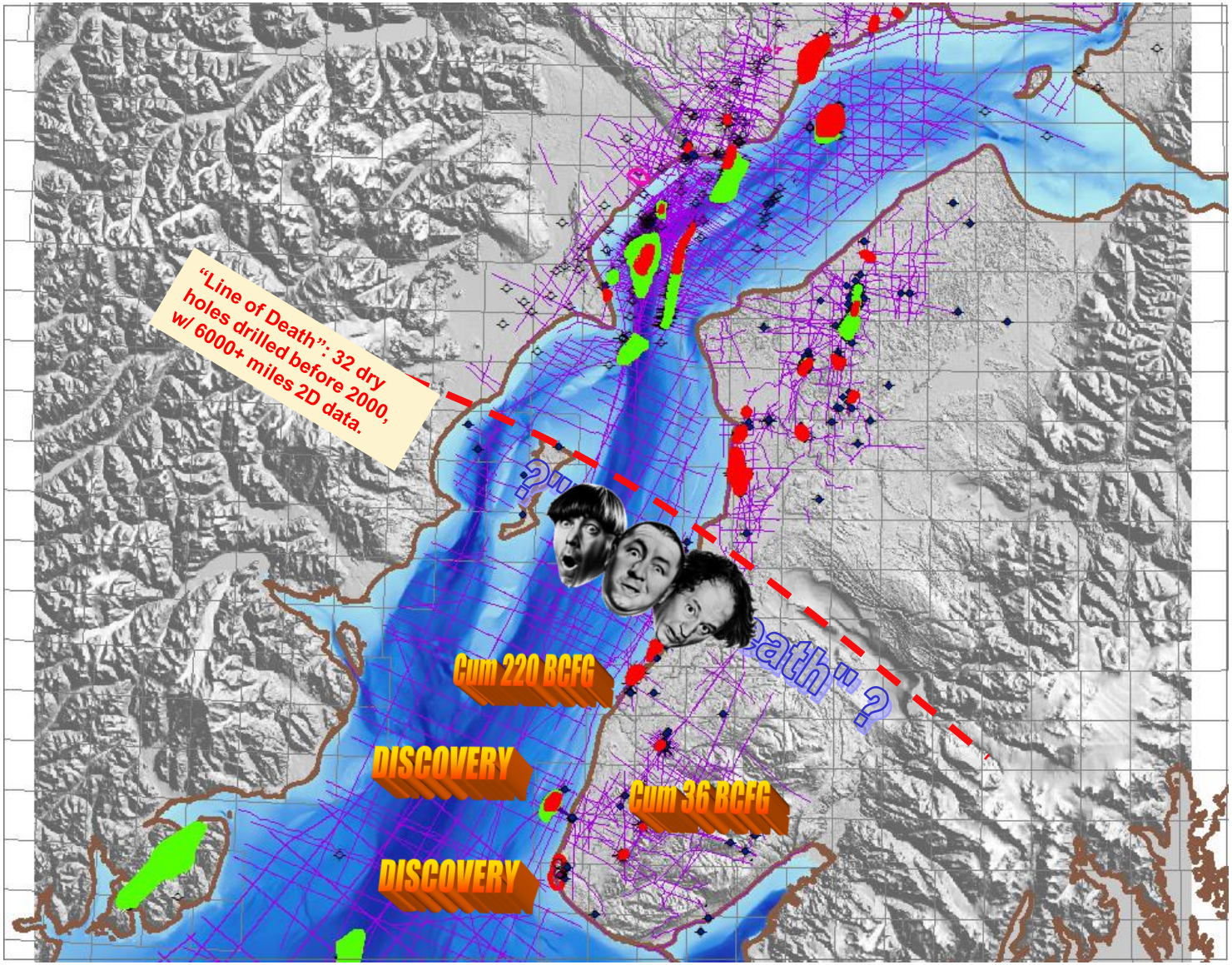
Productivity Plots Per Well



Exploration Snapshot: 2000

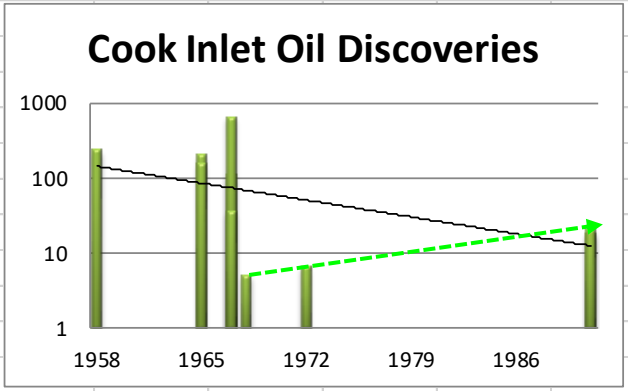


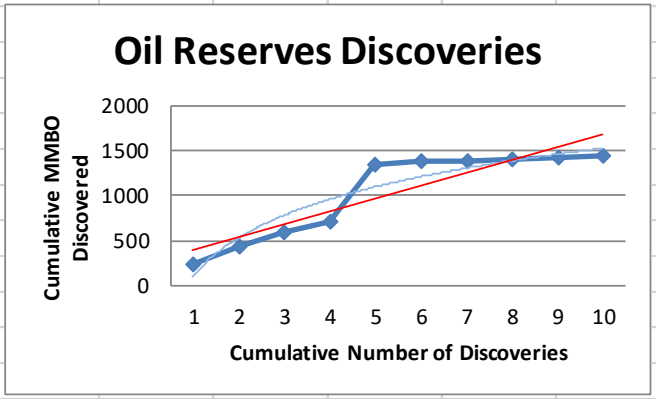
Exploration Snapshot: 2019

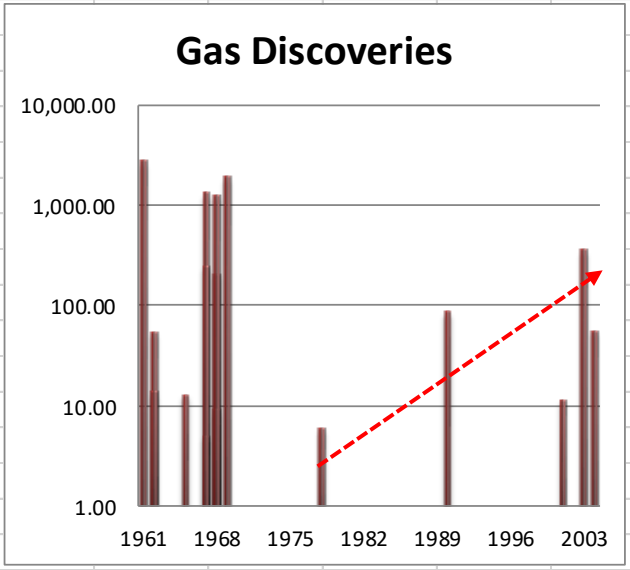


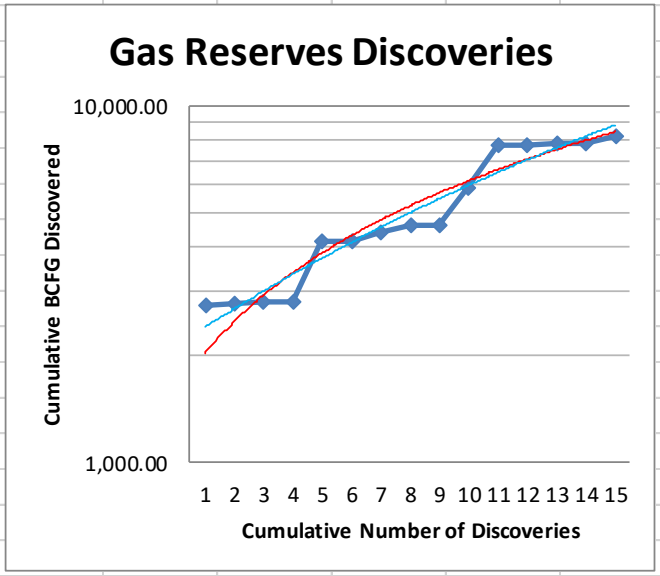
Feedback Loop: Past Discoveries & Prospects

CI Oil Fields Creaming Curves			
FIELD	First Pdn	Cum Oil (MMBO)	Cum MMBO
SRF	1958	235	235
MGS	1965	204	439
GP	1965	155	594
TBU	1967	109	703
McArthur River	1967	646	1349
Hanson	1967	35	1384
Redoubt	1968	5	1389
Beaver Creek	1972	6.6	1395.6
WMR	1991	18	1413.6
NCI	1991	20	1433.6
CI Gas Fields Creaming Curves			Cum BCFG
Kenai	1961	2,737.00	2,737.00
SR	1962	53	2,790.00
Sterling	1962	13.5	2,803.50
North Fork	1965	12.7	2,816.20
Beluga River	1967	1319	4,135.20
Moquawkie	1967	5	4,140.20
Beaver Creek	1967	242	4,382.20
Cannery Loop	1968	205	4,587.20
Nicolai	1968	9	4,596.20
GGS	1968	1246	5,842.20
N. Cook Inlet	1969	1917	7,759.20
West Fork	1978	5.9	7,765.10
Ivan River	1990	85.5	7,850.60
West Foreland	2001	11.2	7,861.80
Ninilchik	2003	353	8,214.80
Happy Valley	2004	55	8,269.80
8/12/2019			









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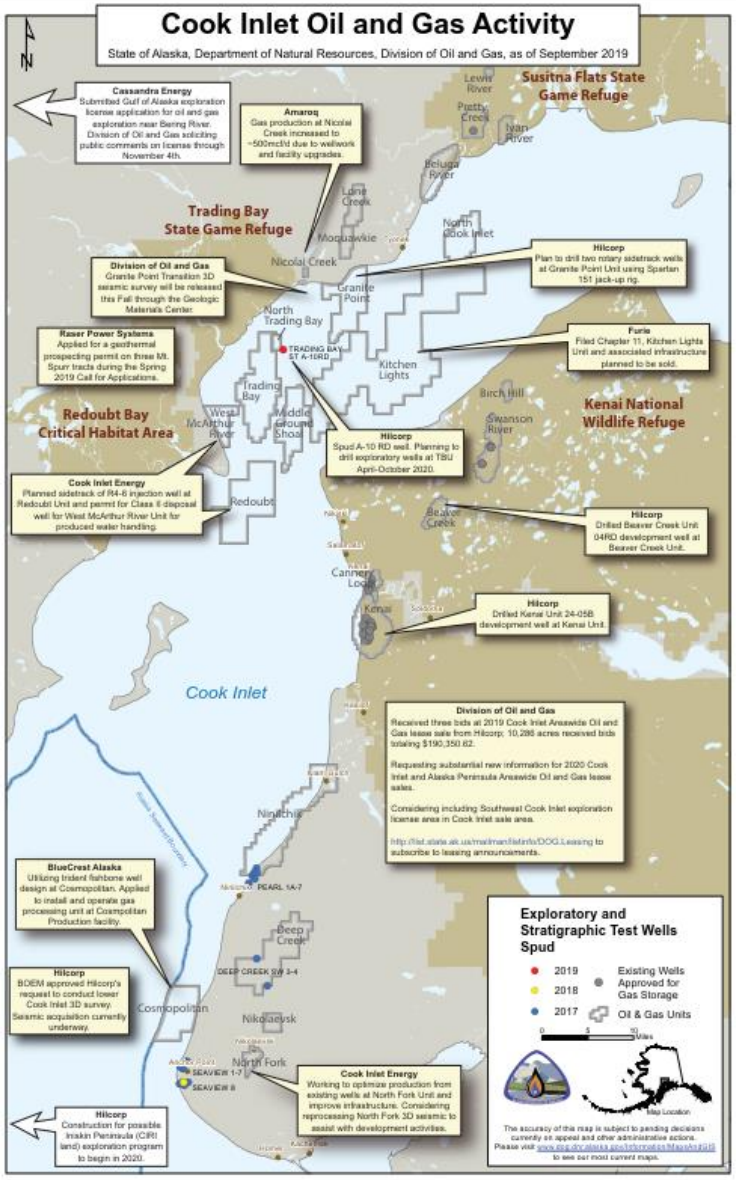
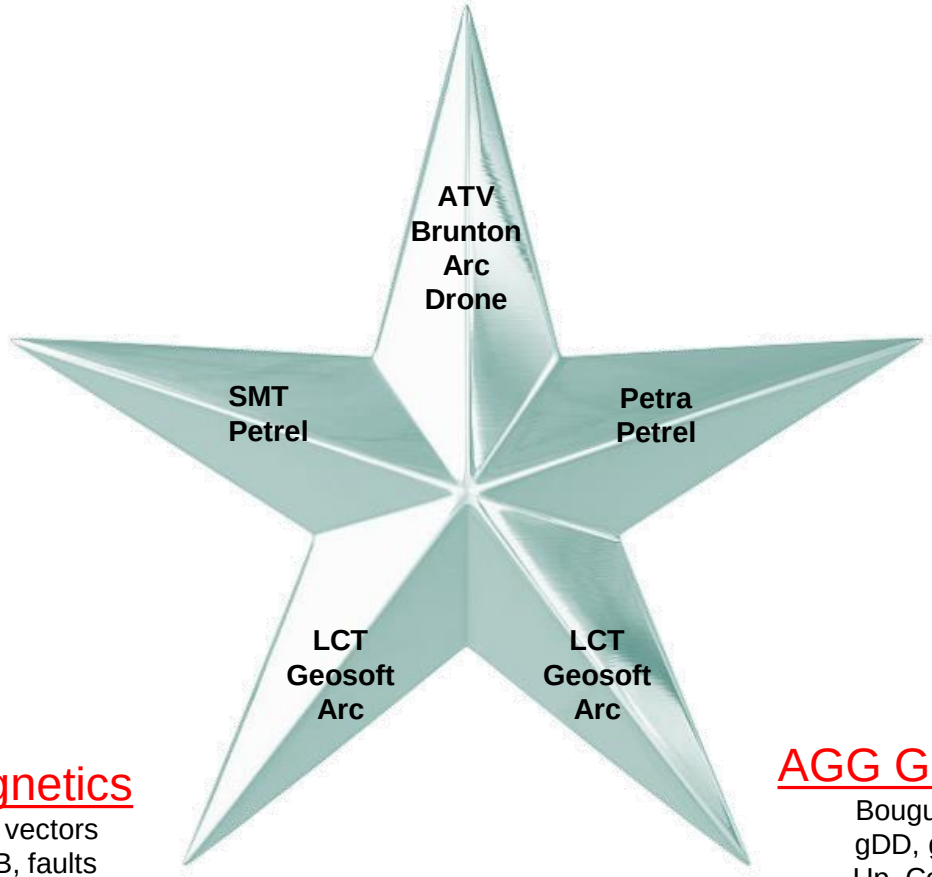
PRESENT EXPLORATION



Exploration Toolbox: Present

Surface
Faults, strike dips
Drainage anomalies
Topography/bathymetry



Seismic
2D, 3D
Class 3, AVO
Desktop reprocess LCT
Bad data areas

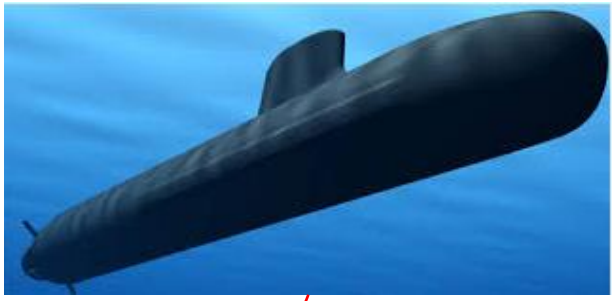
Subsurface
O&G wells
Water wells
Strat tests
Trap indicators
Petrophysics

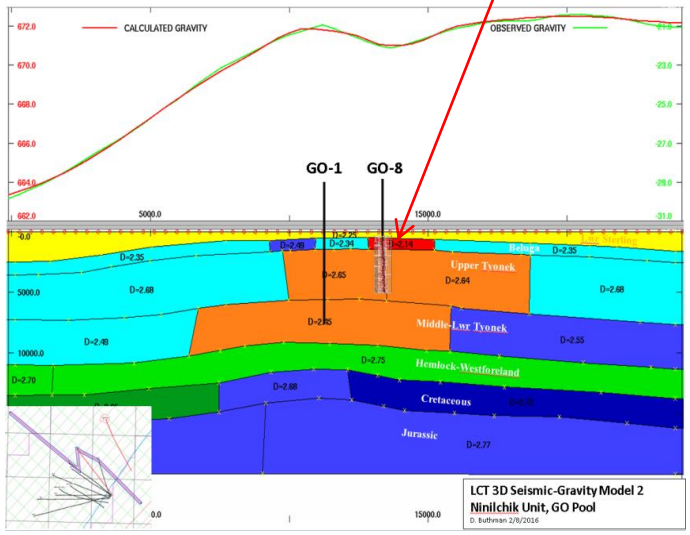
Magnetics
Dip vectors
DTB, faults
TMI RTP
Susceptibilities

AGG Gravity
Bouguer
gDD, gD
Up. Cont
FVD
SVVS Models

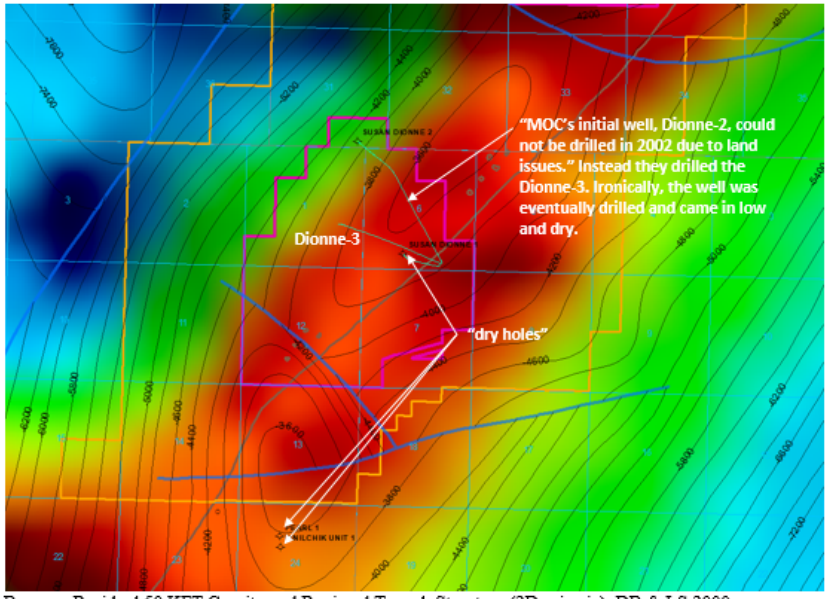
Potential Fields Programs

Geophysical Methods—Gravity & Magnetics: Trap

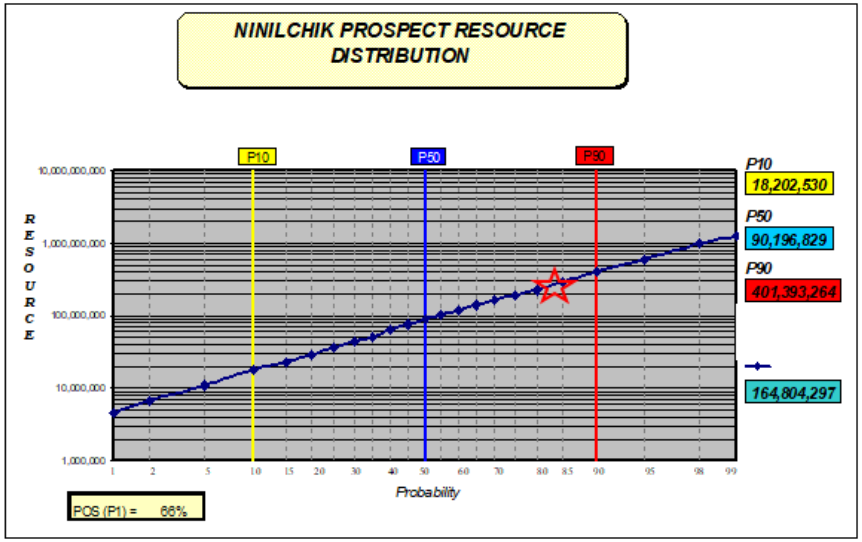




Ninilchik Unit: Past



Bouguer Residual 50 KFT Gravity and Regional Tyonek Structure (2D seismic), DB & LS 2000



Ninilchik Prospect consisted of Falls Creek, GO, and Paxton Pools, which have' cumulated 216 BCFG to date (4/2019). HAK: 45 BCFG booked Beluga PDP + additional 70 BCFG reserve adds (4Q 2016).

Discovery History:

Wells:

- Union 1-Ninilchik, 1962, TD 14940 in Cretaceous, PB, DST Lwr Beluga 3776-86: GTS 1 min, steady light blow gas and water; suspended.
- Mobil 1-Ninilchik Unit, 1964, TD 12724 in Cretaceous, P&A
- Union 1-Pearl, 2002, TD 8000' Tyonek, Perf 4008-43: 980 to 1025 psi, lit flare F/125 MCFGD w/5694-34' perfs, found fluid level, hard gas blowdown when P&A
- Marathon 3-Dionne drilled 2002 TD 10300 Tyonek; perf 9283-98, TP increase 1150 to 1410 in 40 mins in N2, F/ 5.52 MMCFGD @2200 psig, DISCOVERY

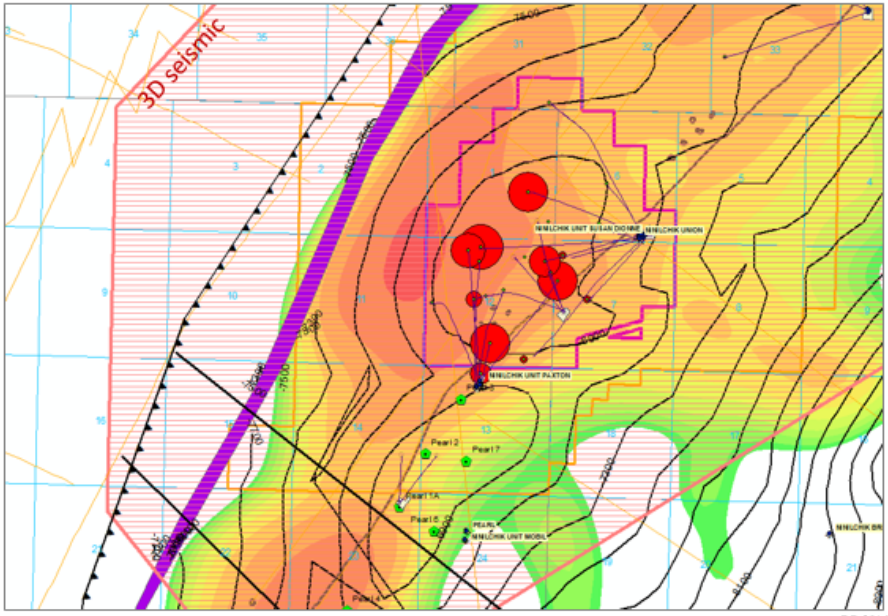
Exploration Methods leading to Discovery :

Union 1-Ninilchik and Mobil 1-Ninilchik drilled based on poor quality 2D seismic searching for Hemlock oil. Union 1-Pearl drilled based on poor quality 2D seismic data, gravity not considered. Union had nearly 100% of the pool leased prior to discovery based on gravity, surface geology, 2D seismic, and a dipmeter in the Union 1-Ninilchik, which showed true dip in the OPPOSITE direction to that indicated by the 2D seismic data. Union contributed the leases to the eventual Marathon-operated unit and joined in drilling the Dionne-3 well.

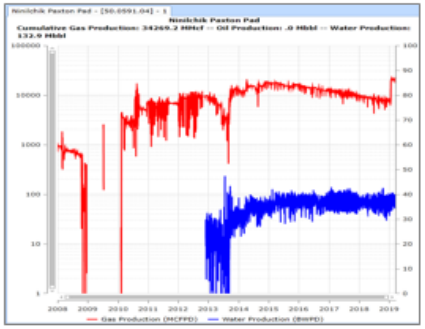
Exploration Program post-mortem:

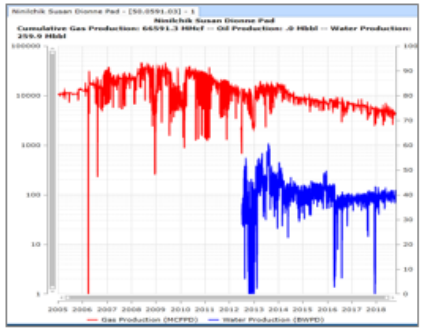
Poor 2D seismic mislead explorers and delayed discovery, evidenced by fact that this is the largest most prolific pool in the Ninilchik structure. More emphasis on better gravity data and earlier acquisition of good quality 3D seismic data would've accelerated development. Using gravity to reprocess seismic data would have greatly increase accuracy and well placements. The last well drilled by Marathon, the Dionne-7 drilled in 2011, was designed as a fault sliver stepout based solely on 3D seismic, which was a bust.

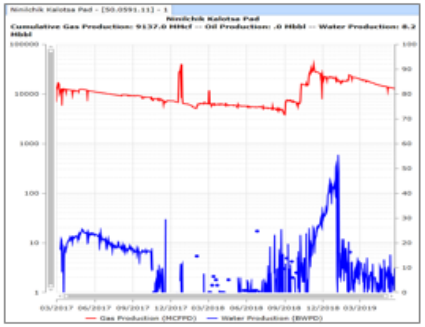
Ninilchik Unit: Present



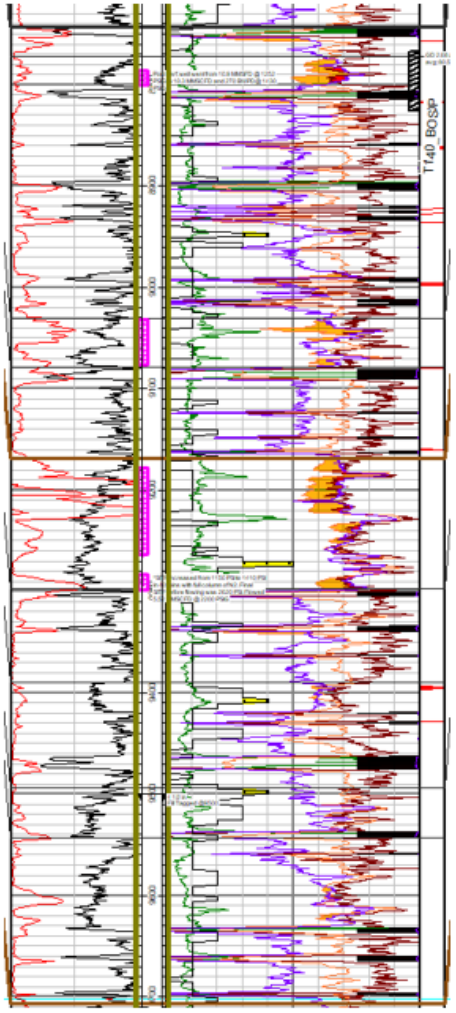
AGG Bouguer Gravity GDD MF 4.3 km and Regional Tyonek T-90 Structure (3D seismic).







Dionne #3

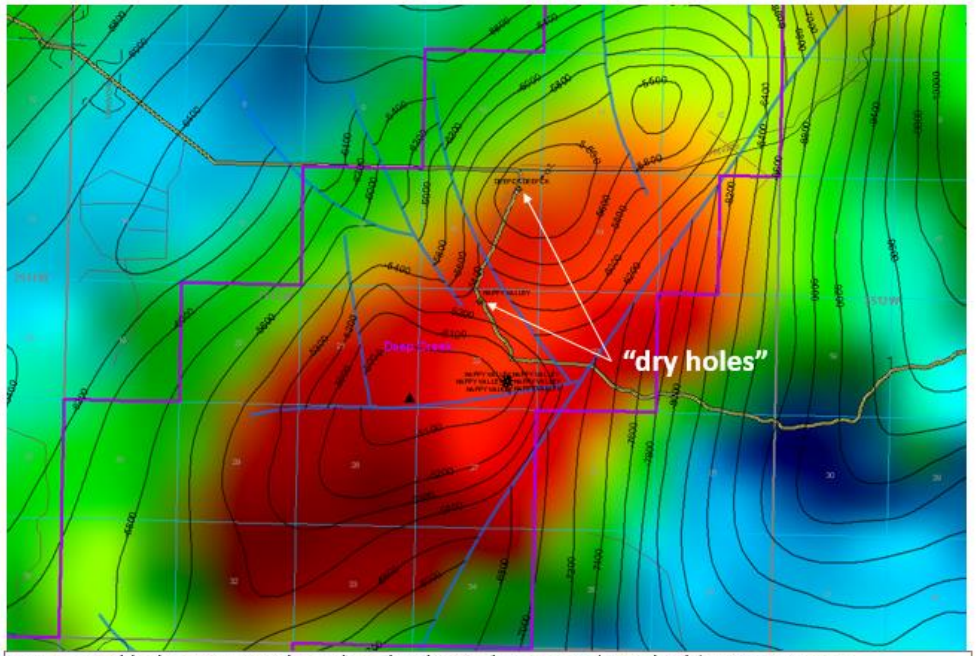


Post-Discovery History:

Wells:

- Dionne 3 cum'd over 17.9 BCFG, producing 699 MMCFGD
- 18 wells drilled from 2003-2015: 17 gas wells, 1 well dry
- Cumulative production: 110 BCFG; current production: 39.143 MMCFGD
- Hilcorp Activities since taking over:
  - Increased production from 13.89 to 21.95 MMCFGD
  - Proved up Upper Beluga to Blg-135 via RTP, perf adds, and drilling
  - Drilled Dionne-8, Paxton 5, 7, 8, 9
  - Built Kalotsa Pad, drilled 4 gas wells
- Development Program post-mortem:
  - Follow up discovery with the best gravity and 3D seismic data acquisitions; pause and evaluate; then follow with slow delineation, running dipmeters in each well, and developments. No batch drilling. Caution using 2D and 3D seismic. Marathon's last well, the Dionne-7, drilled a 3D seismic false upthrown fault anomaly.

Deep Creek Unit: Past



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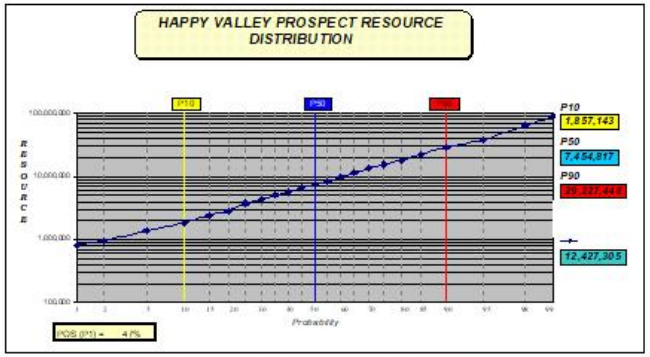
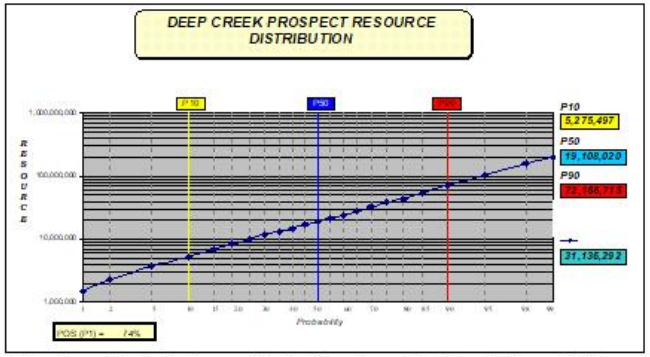




The Deep Creek Unit consisted of the Deep Creek and Happy Valley Prospects. Together the Mean pre-drill resource was 43.5 BCFG, of which 36 BCF has been produced, with upside remaining.

Discovery History:

Wells:

- DCU-1 drilled 1958 on Deep Creek Prospect, TD 14221' in Cretaceous, P&A'd
- HV 31-22 drilled 1963 TD 13550' Hemlock P&A'd
- NNA-1 drilled 2001 TD 10590' in Tyonek, converted to SWD after numerous wet/tite tests
- HV-1 drilled 2003 TD 10872 in Tyonek; perf Tyonek 9746-86 F/ 4.1 MMCFGD @1055 psi, DISCOVERY

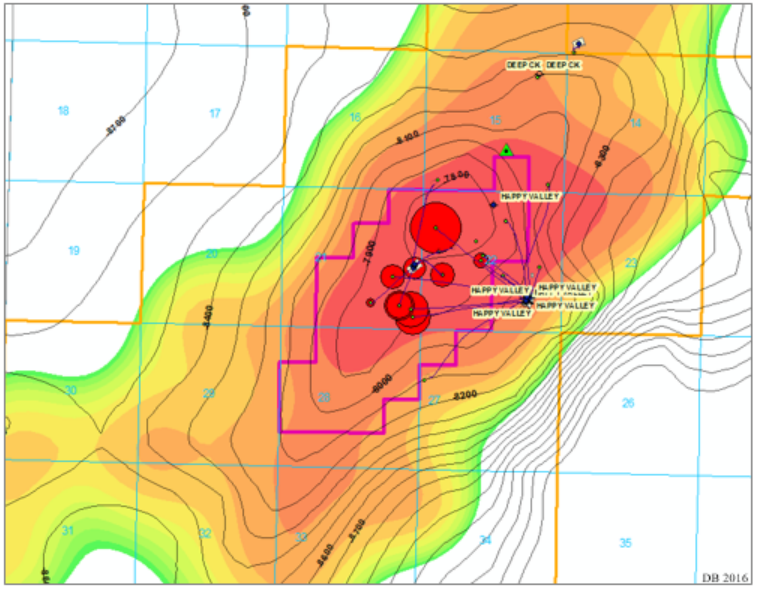
Exploration Methods leading to Discovery :

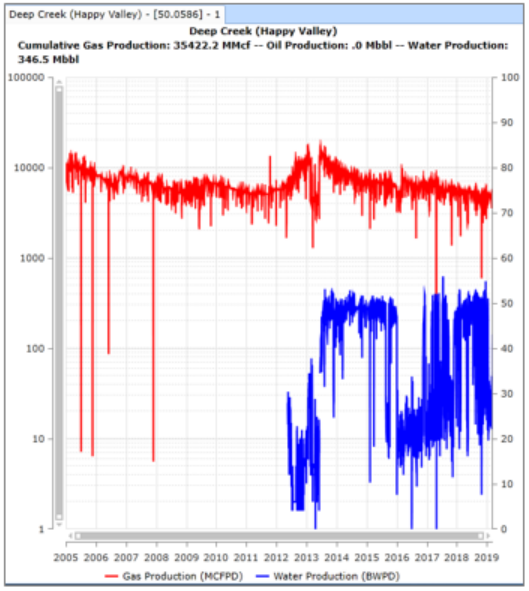
DCU-1 and HV 31-22 drilled by Socal and Superior based on poor 2D seismic and trail-gravity data. Unocal 1-NNA drilled 2D seismic bust. HV-1 drilled by Unocal based on better gravity and seismic data.

Exploration Program post-mortem:

- The NNA-1 was drilled down the flanks of the gravity high on an inaccurate 2D seismic high. To avoid this in the future, the gravity and seismic data must match, and density models made to uncover inconsistencies.

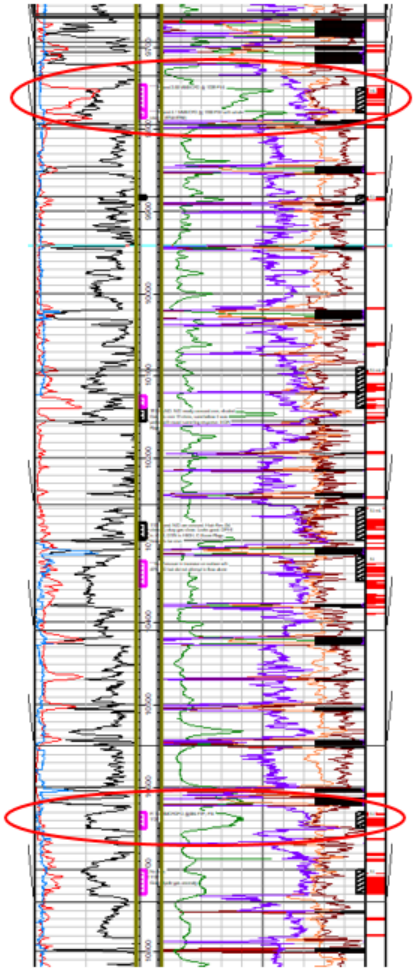
Deep Creek Unit: Present





AGG Bouguer Gravity GDD MF 4.3 km and T-70 Structure

Happy Valley #1

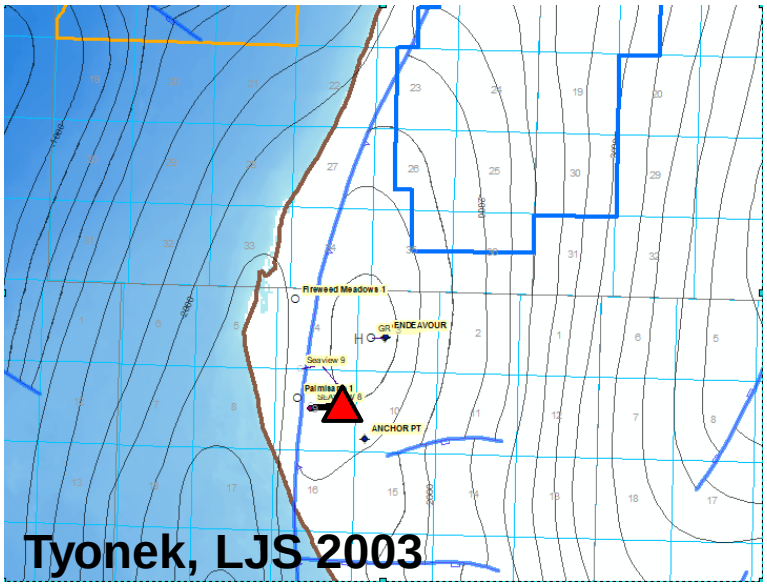


Post-Discovery History:

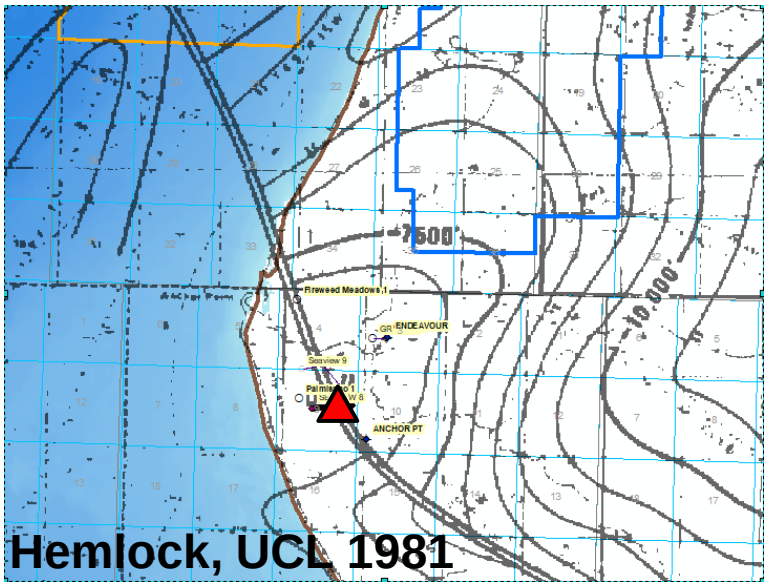
Wells:

- HV-1 cum'd 4.9 BCFG
- 16 wells drilled from 2003-2015
  - 10 gas wells: 6 wells Dry or J&A'd. Note: HV 3, 4, and 5 were batch drilled while 2D seismic was being shot, and HV 6, 7 were drilled down-dip and through the fault to the north.
- Cumulative production: 36 BCFG; current production: 4.847 MMCFGD; EUR: 54.8 BCFG (AM, 5/2019)
- Hilcorp Activities since taking over:
  - 3D survey 2013
  - Drilled HV-14, HV-15, and HV-17 gas wells, and the HV-16 T&A'd
- Development Program post-mortem:
  - Follow up discovery with the best gravity and 3D seismic data acquisitions; pause and evaluate; then follow with slow delineation and developments. No batch drilling.

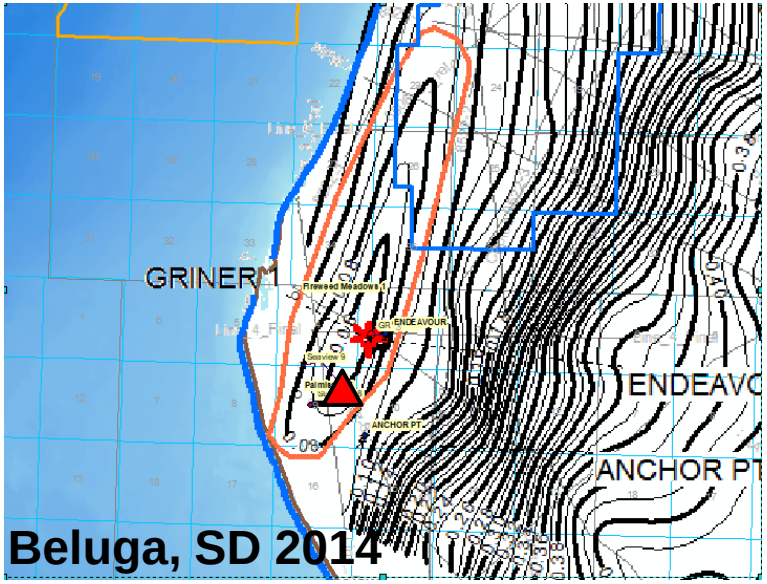
Seismic Interpretation Variability @ Seaview Prospect



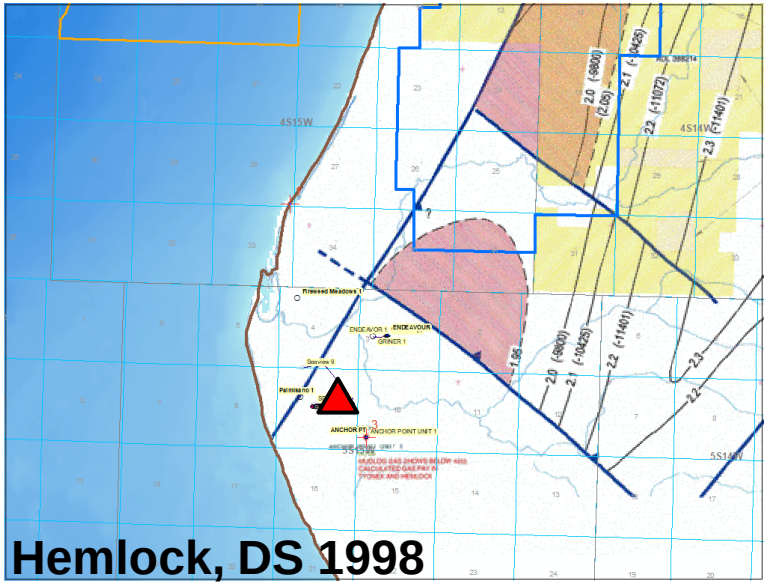
Tyonek, LJS 2003



Hemlock, UCL 1981

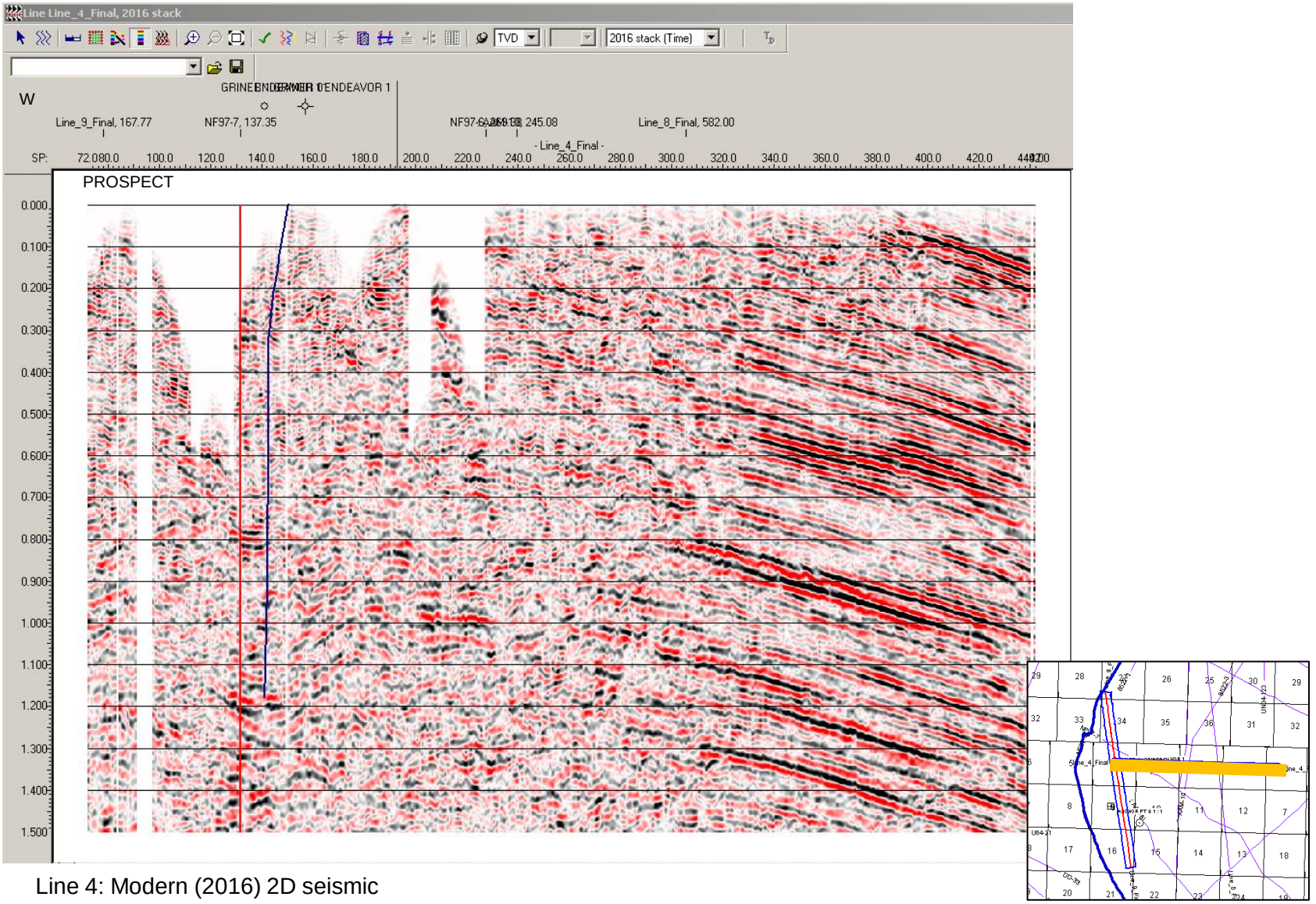


Beluga, SD 2014



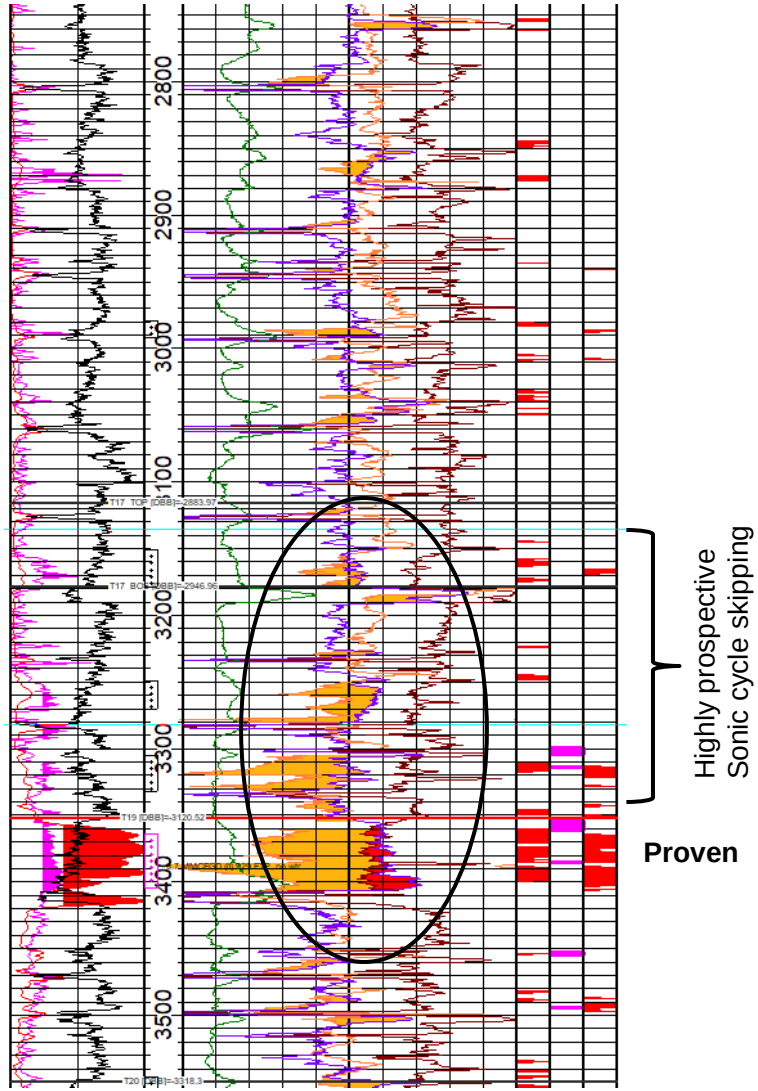
Hemlock, DS 1998

Why Strat Test Wells?

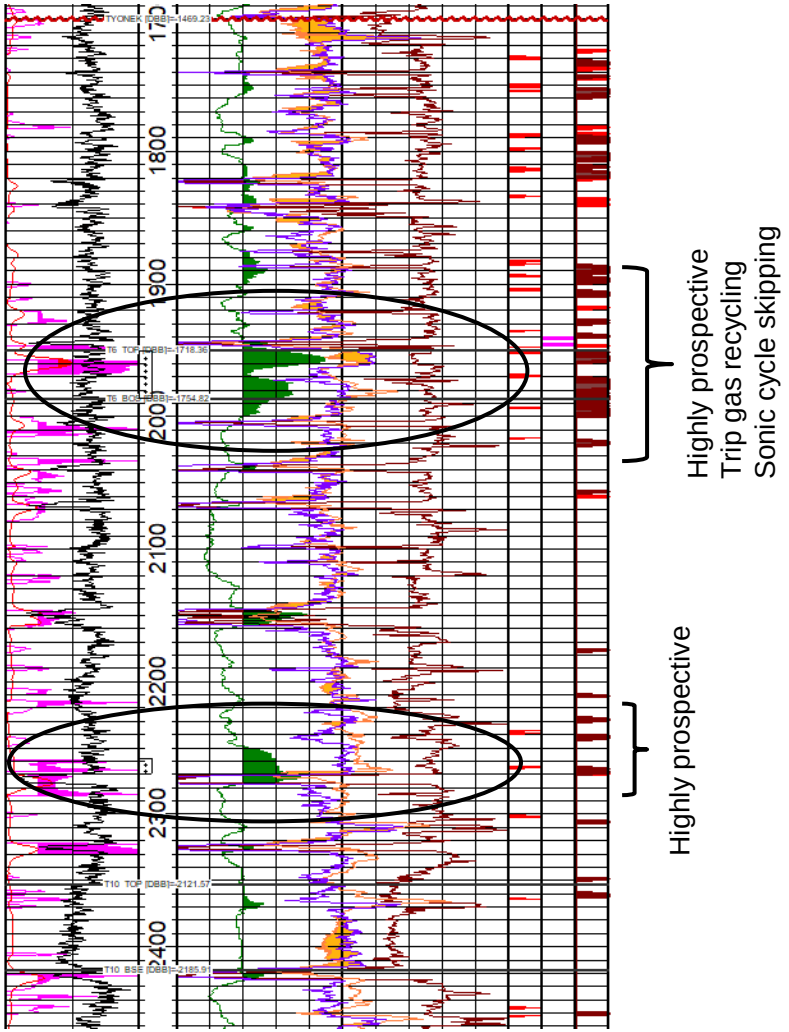


Line 4: Modern (2016) 2D seismic

Seaview 8 Potential Gas Pays

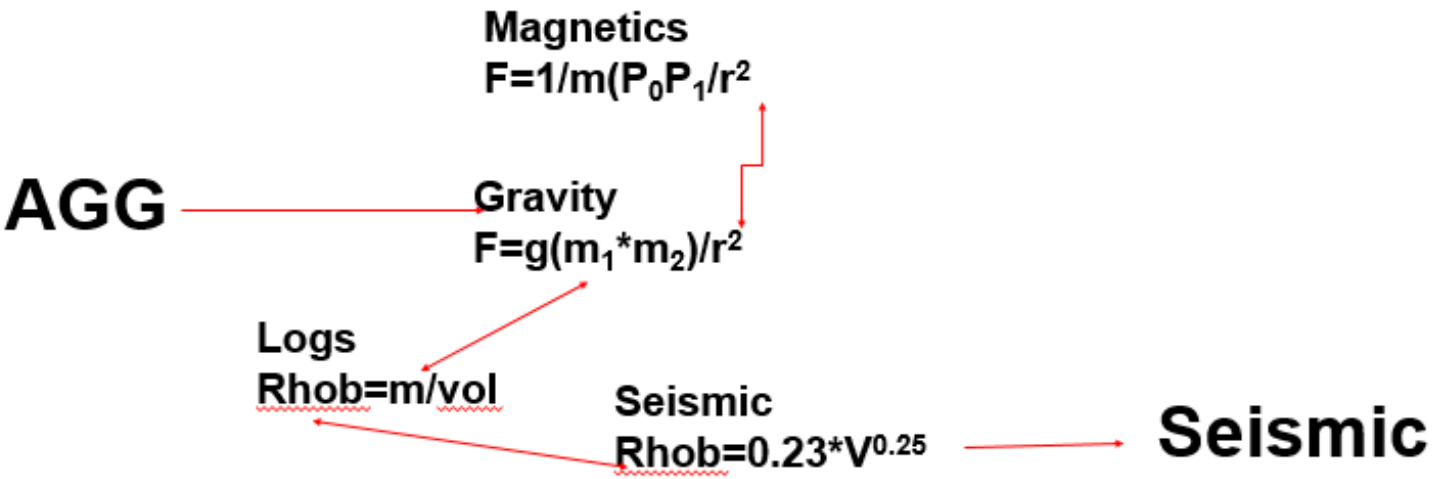


T-17 through T-19

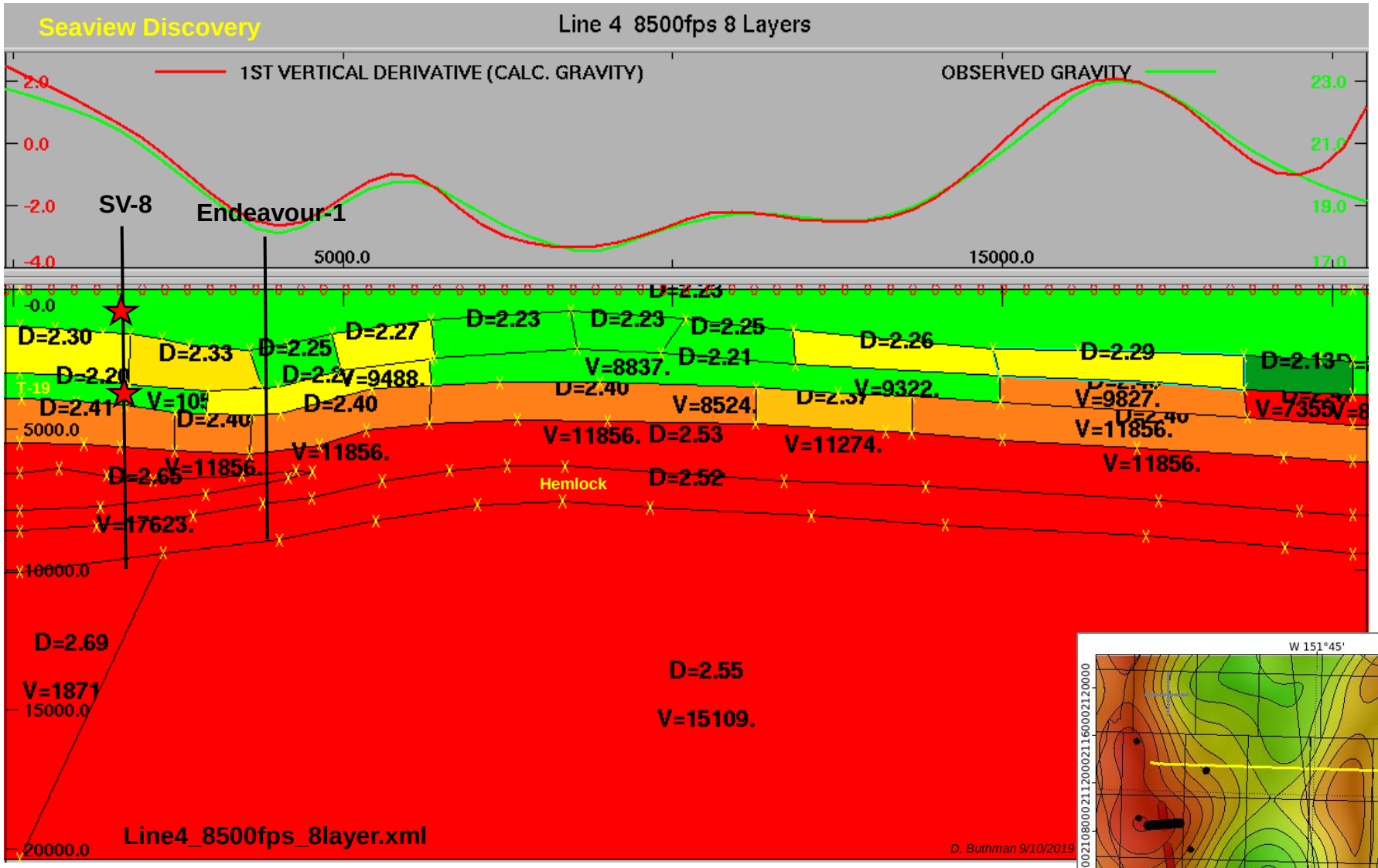


Top Tyonek Through T-9

Seismic Velocity Verification

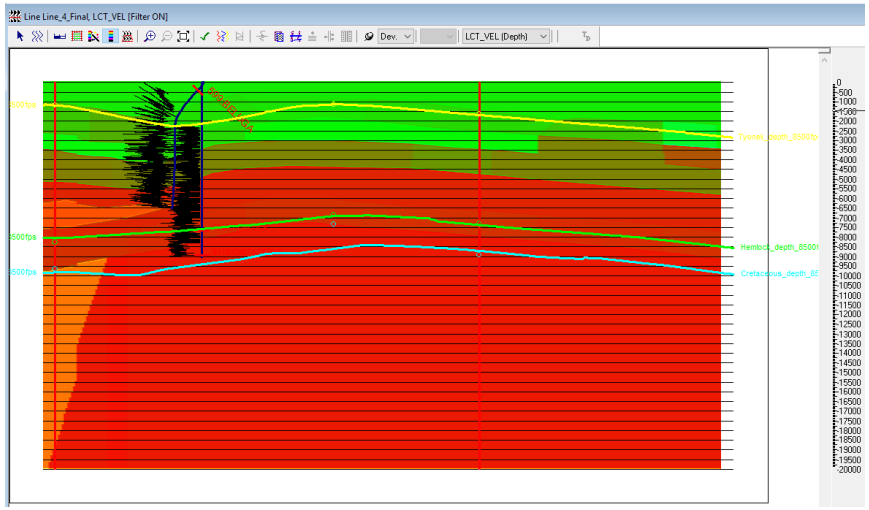


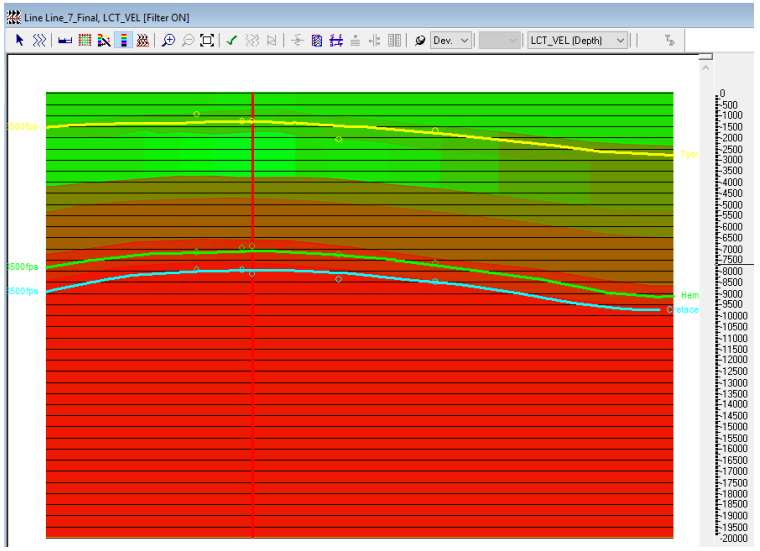
Seismic-Gravity Density Models

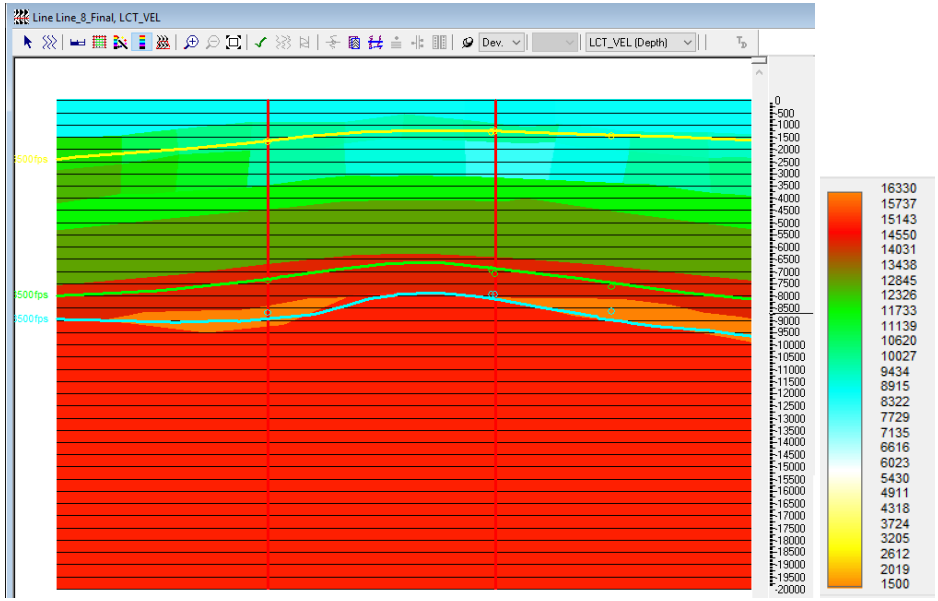


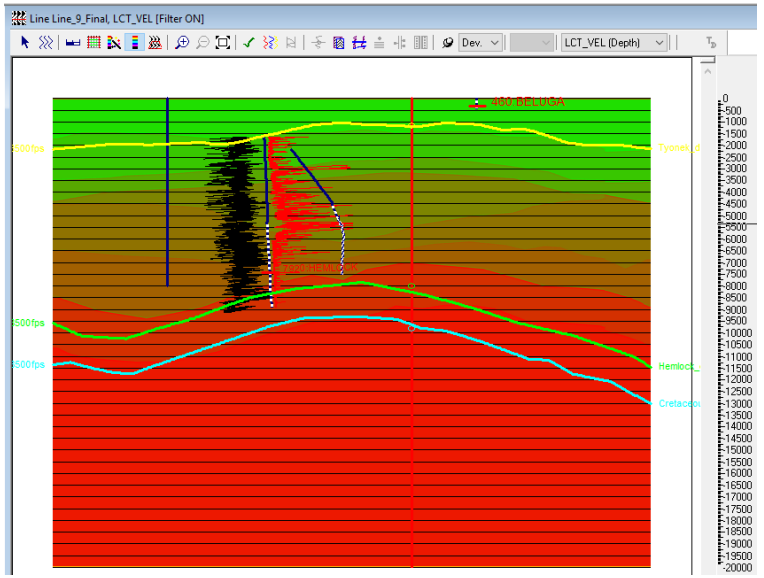
8-Layer LCT model showing known T-19 discovery zone at SV-8 well, correct structural relationships between the Endeavour-1 and the SV-8 wells, and matching density-velocity inversions. Prospective section is ~-900 to -3600' depths.

Invert Velocity from Density Models, and use to Depth Correct Seismic Sections

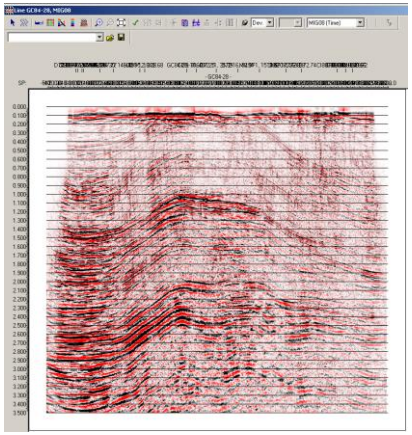




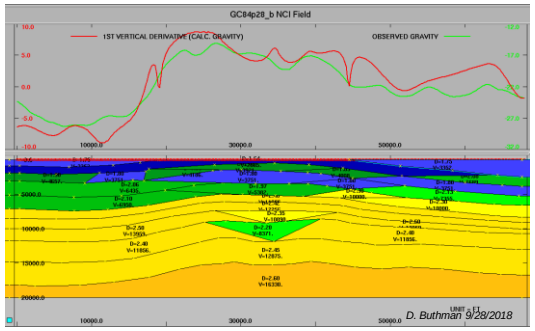




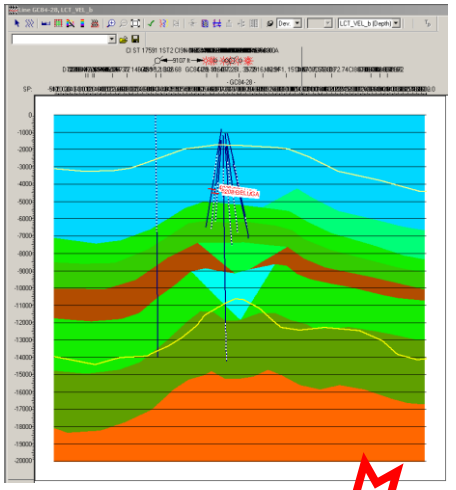
Velocity Control for Seismic Data

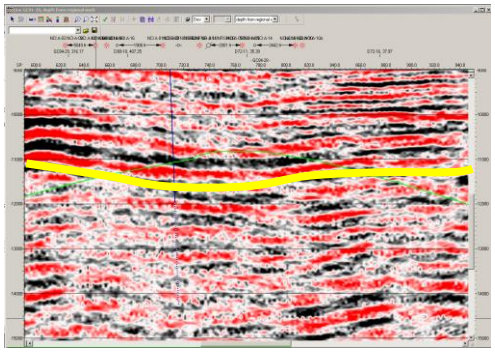


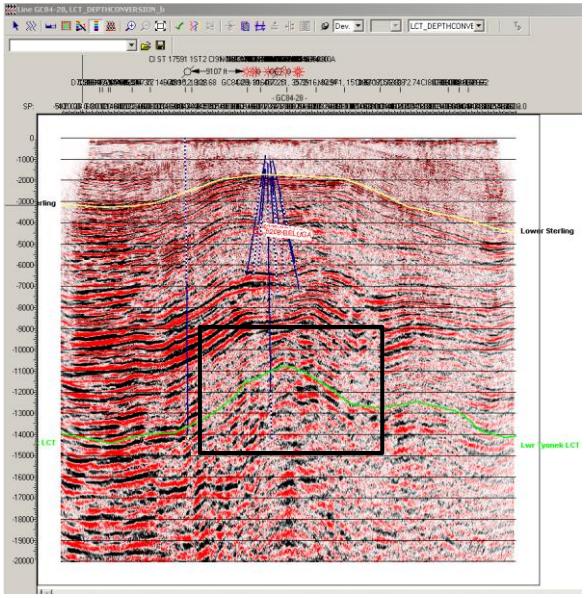
Mig08 time section

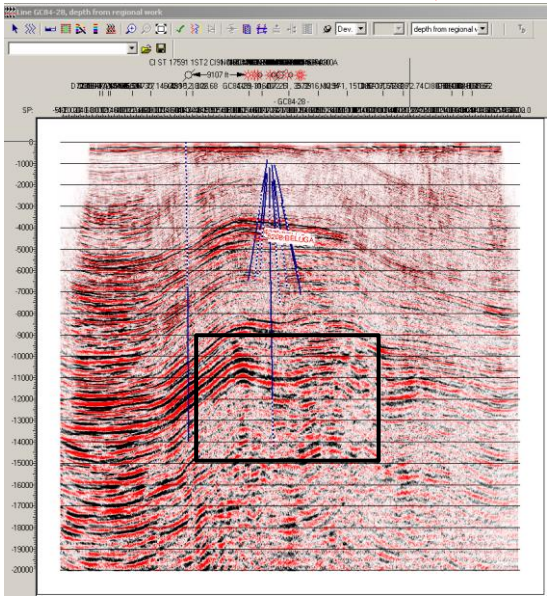


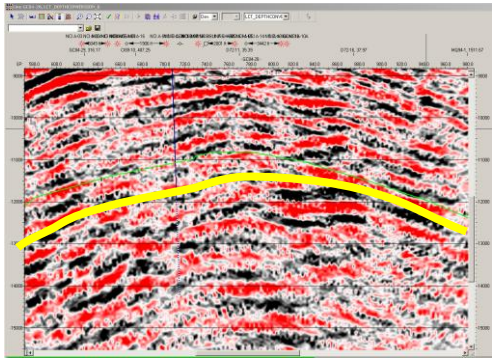
LCT 2Model 3 for velocity inversion export.











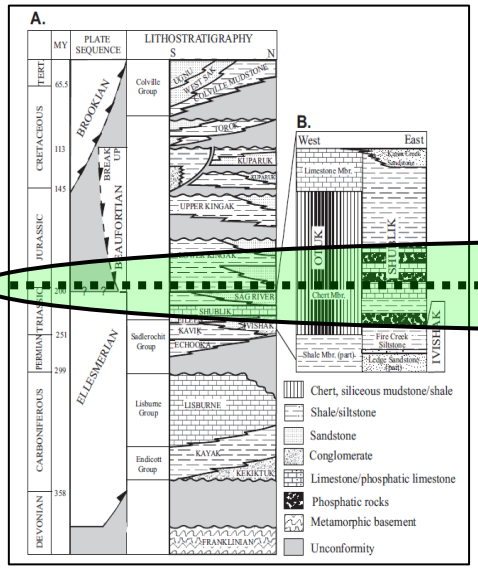
3rd Iteration of gDD velocity inversion reprocessed 2D seismic line in depth.

Legacy depth section from regional work.

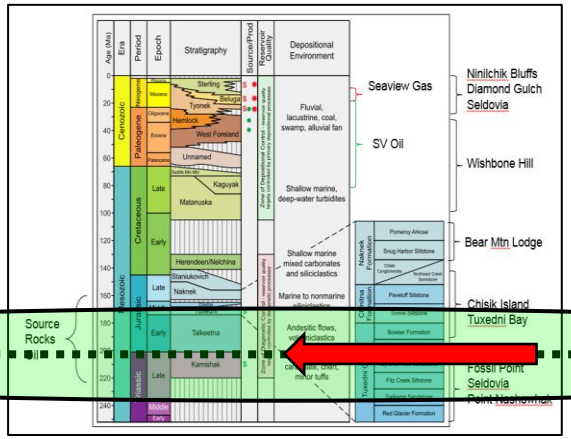
FUTURE EXPLORATION

Hypotheses …

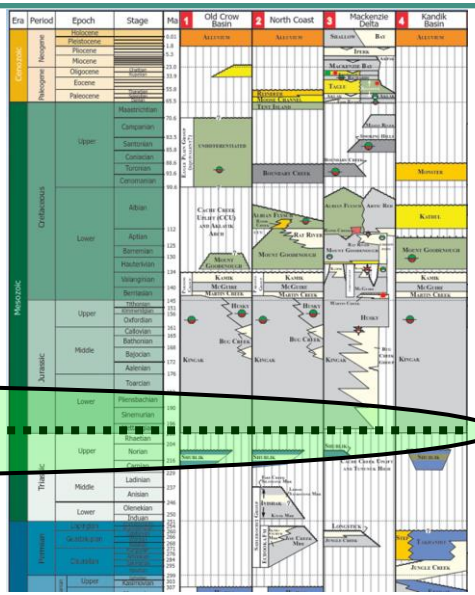
Alaska Basins: Oil Source Rocks: LJ-UT



Shublik Formation source rocks, N. Slope

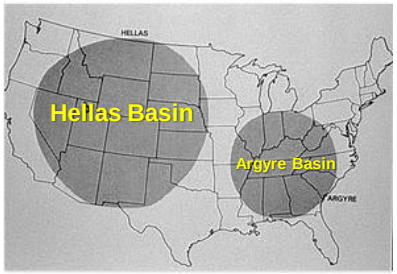


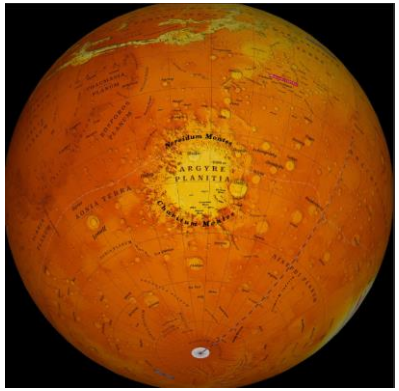
Tuxedni Formation source rocks, Fossil Point, Tuxedni Bay.

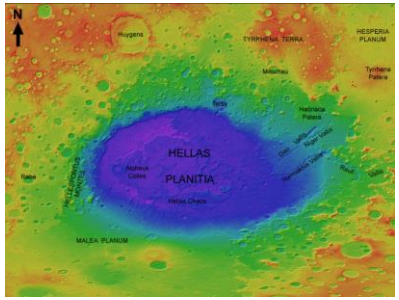


Oil source rock distribution for Upper Triassic-Lower Jurassic (~Glenn Shale).

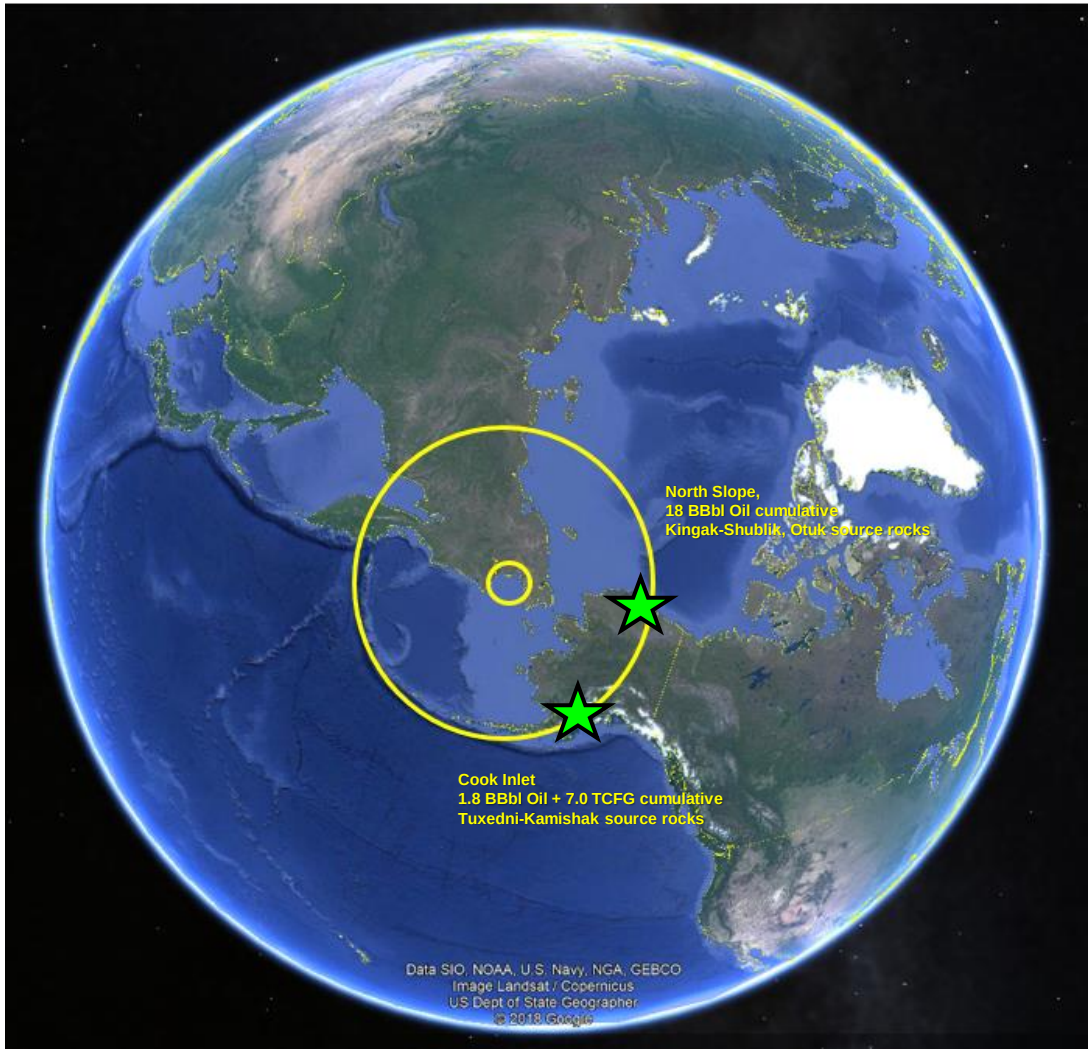
Global View: Upper Triassic to Lower Jurassic Oil Source Rocks





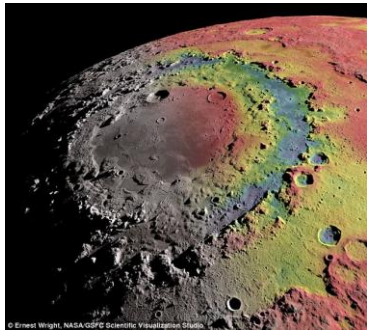


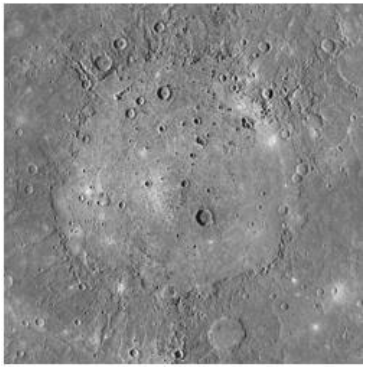
Top: scale comparison of large Martian craters with Earth. Argyre Basin, Mars: 1100 mile diameter. Bottom: Hellas Basin, Mars, 1400 mi diameter

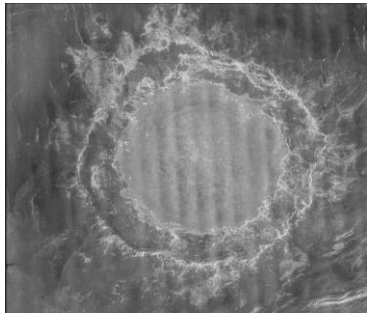


Aleutian Crater, Earth: 1700 mile diameter

D. Buthman 12/31/2019

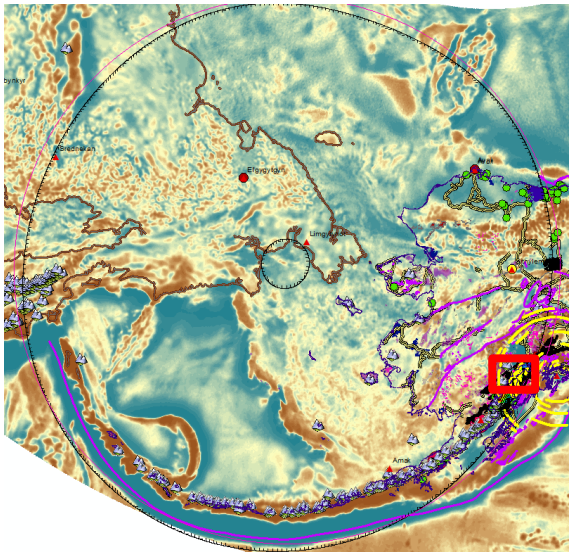






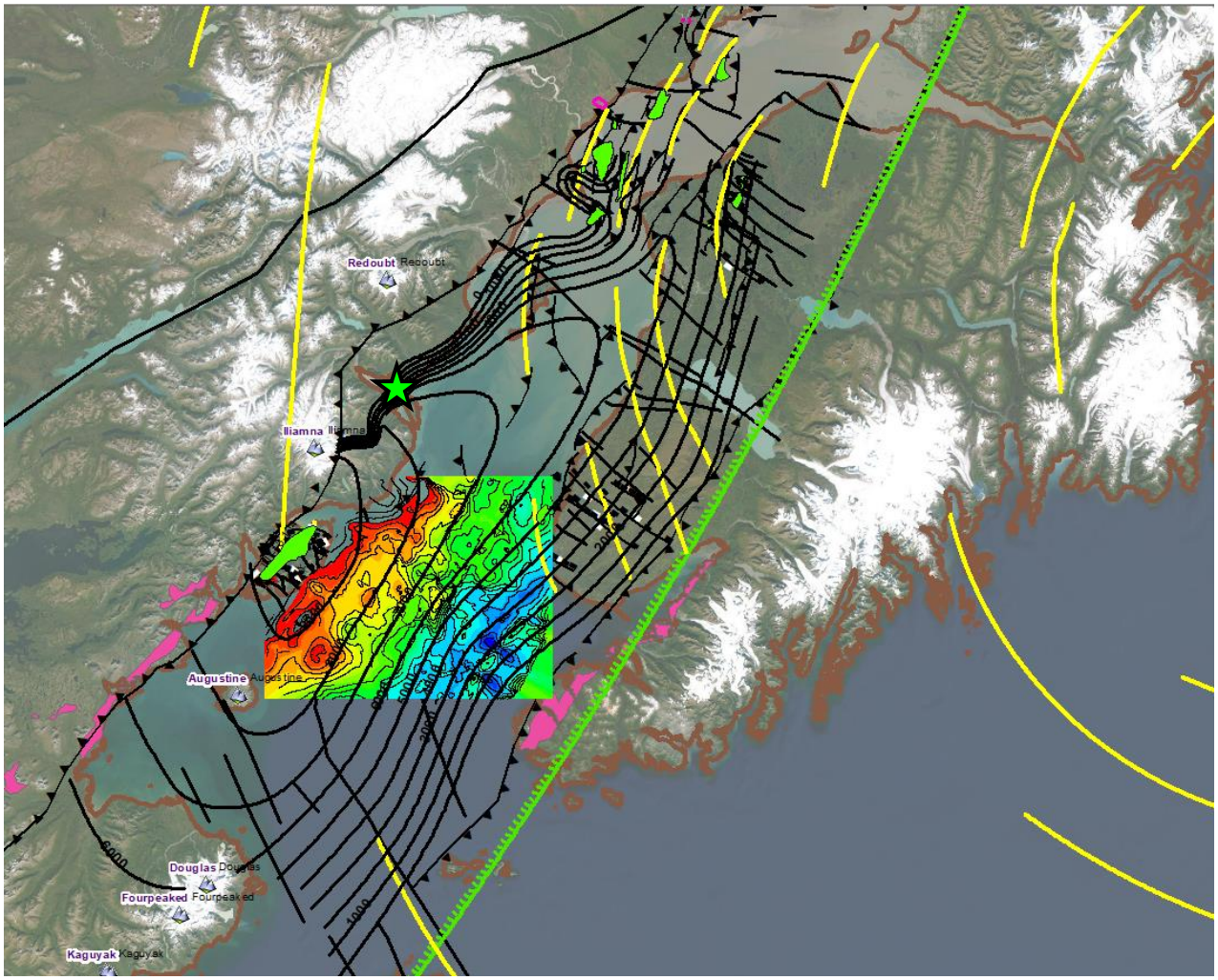
Top: Mare Orientale, Moon: 560 mile diameter. Caloris Basin, Venus: 960 mile diameter. Bottom: Mead Crater, Venus: 174 mile diameter.

Tuxedni Source Rock Isopach



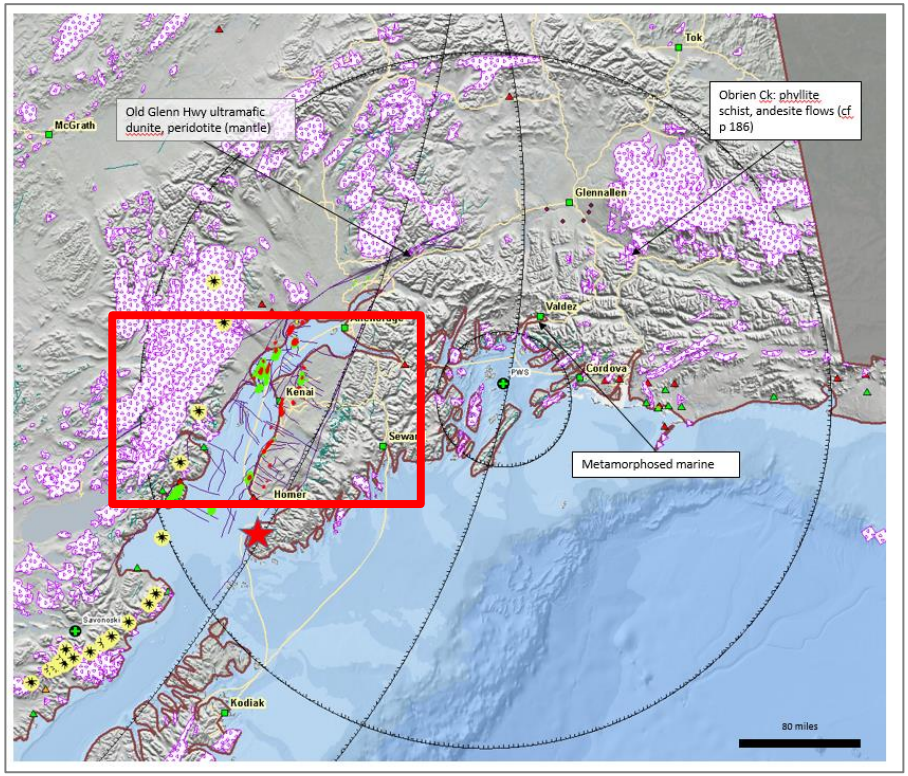
Sandwell Free Air gravity and crater interpretations.

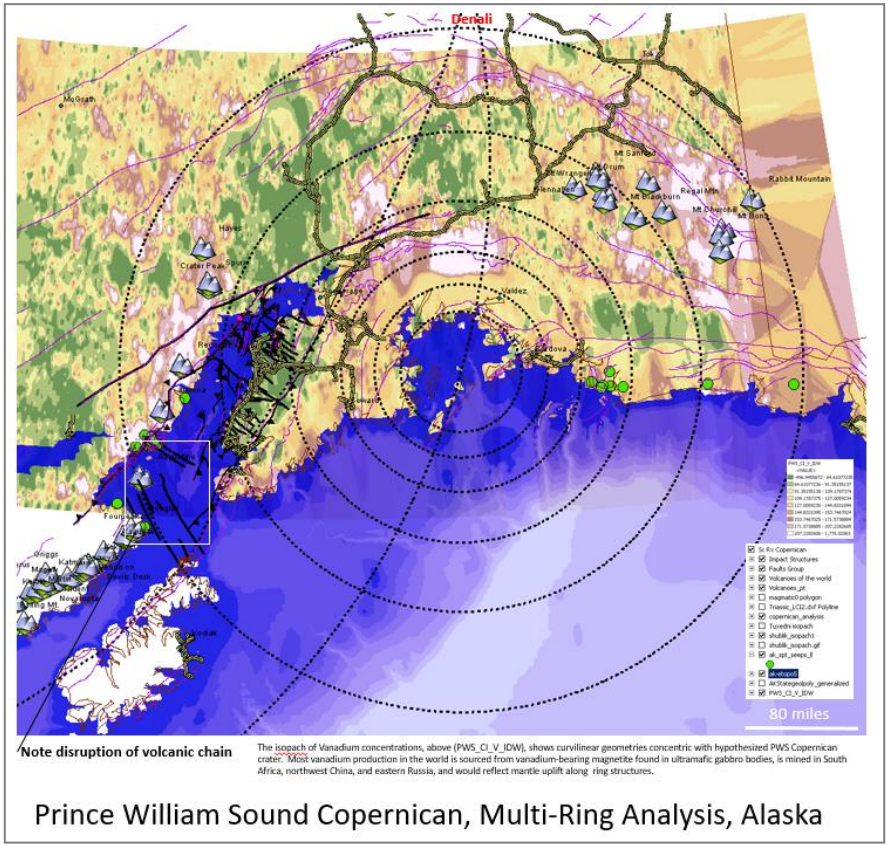
Tuxedni Formation source rocks, Fossil Point, Tuxedni Bay.



Cook Inlet Lower Jurassic Tuxedni source rock isopach, and Jurassic to Triassic Isochron, coincides with Anadyr-Aleutian slump terraces.

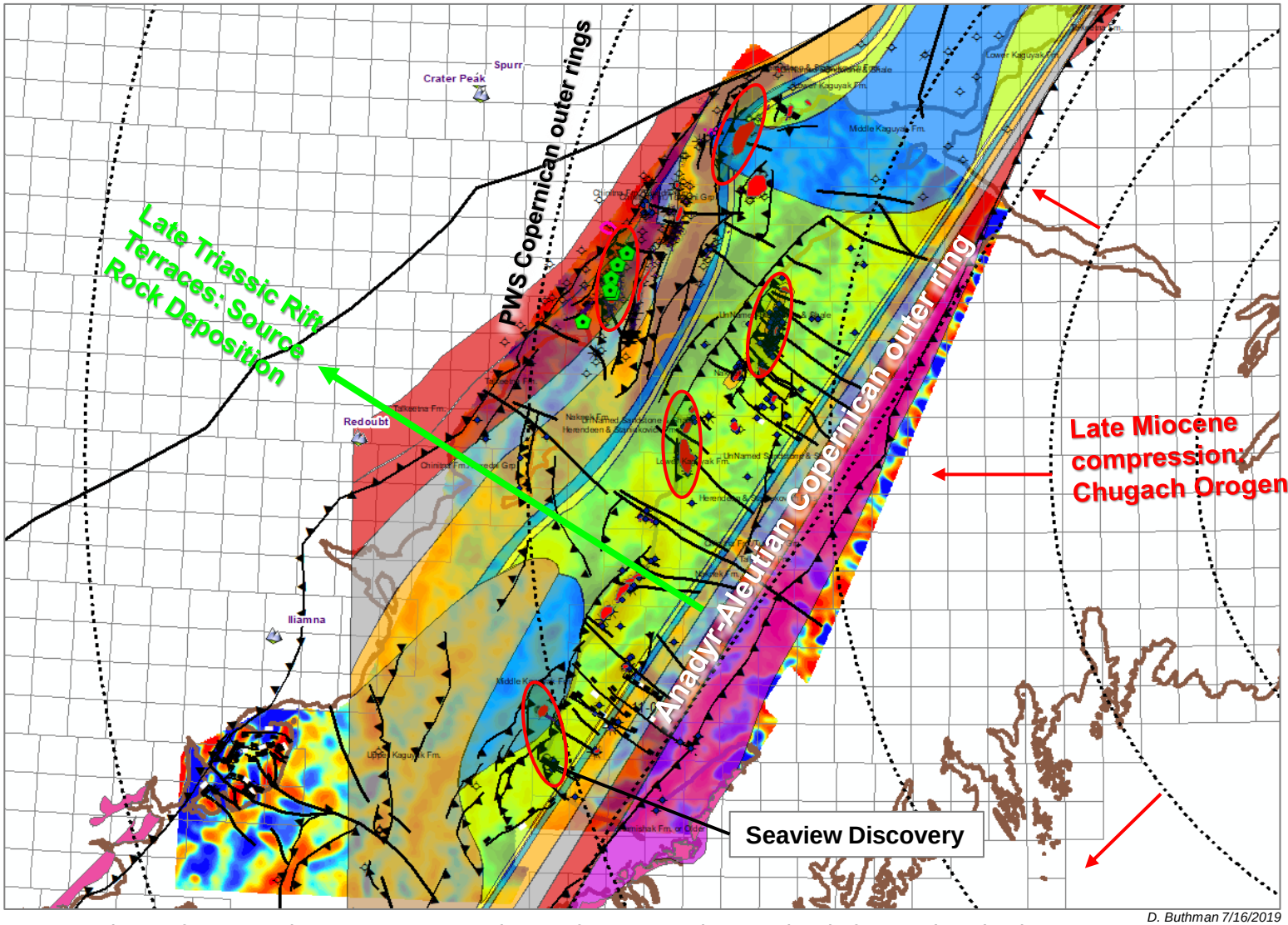
PWS





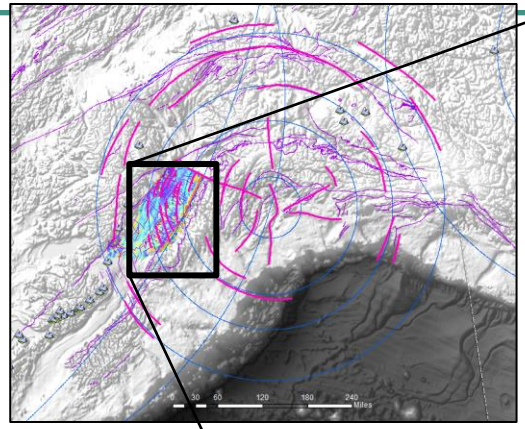
Prince William Sound Copernican, Multi-Ring Analysis, Alaska

Mesozoic Subcrops: Oil Source Rocks

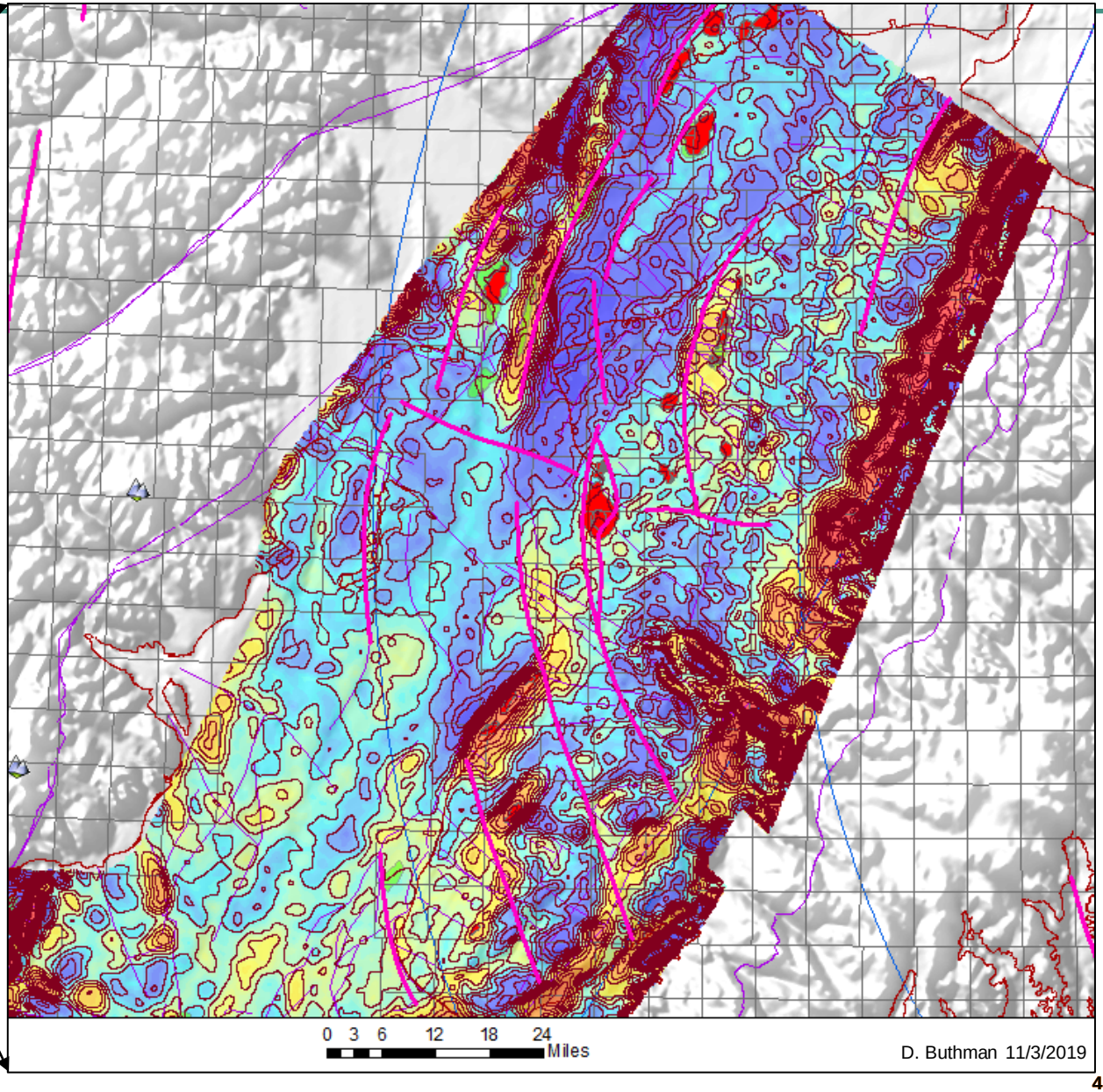


Suggested ages for Copernican events: Later Miocene for PWS and Late Triassic for Anadyr-Aleutian events.

Trap Formation Timing



Curvilinear interpretation of geologic structures, faults, and fields, relative to topography and gravity. Compare these interpretations to the geometric Copernican ring elements forecast in blue. Map, right: shaded relief, lineation analysis, Cook Inlet gravity.



Petroleum Geologists' Greatest Fears

- Stopping drilling a well just above the main pay zone
- Drilling through the main pay zone and not recognizing it
- Condemning a prospect and it comes in
- Getting close but not close enough

Conclusions—Lessons Learned

1. **Post-Mortem Analyses:**
   - Studying what went wrong in the "success leg" is as important as the dry hole leg
   - The importance of "trap indicators"
   - Post-mortems during the corporate layoff years of 1980's-2000's were generally lacking
2. **Tools:**
   - Use conventional and new unconventional tools to identify exploration opportunities, and leverage them given success. Avoid 'ruling theories"
3. **Leverage:**
   - A successful program in a new area can yield abundant profits in that area; while a new tool applied successfully can be leveraged profitably across the globe.
4. **The exploration "feedback loop" spans decades**
   - It spans companies and generations …
   - Recognition of the Griner-1 being a "trap indicator" plus a future employed technology (tool) 16 years later resulted in Hilcorp's Seaview discovery.

"The important thing is to not stop questioning. Curiosity has its own reason for existing."