# Apex Spectral Technology, Inc

*Presents ADF®*

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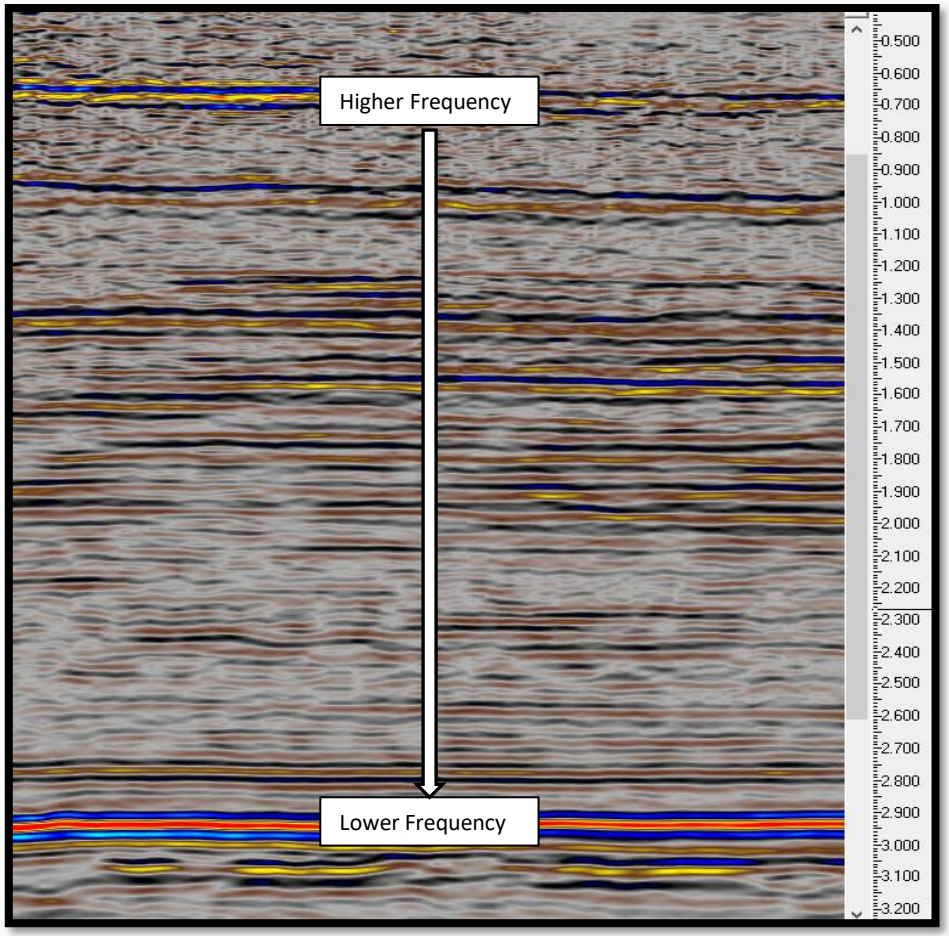
***Imaging Fluid Mobility to Leverage E&P Success***

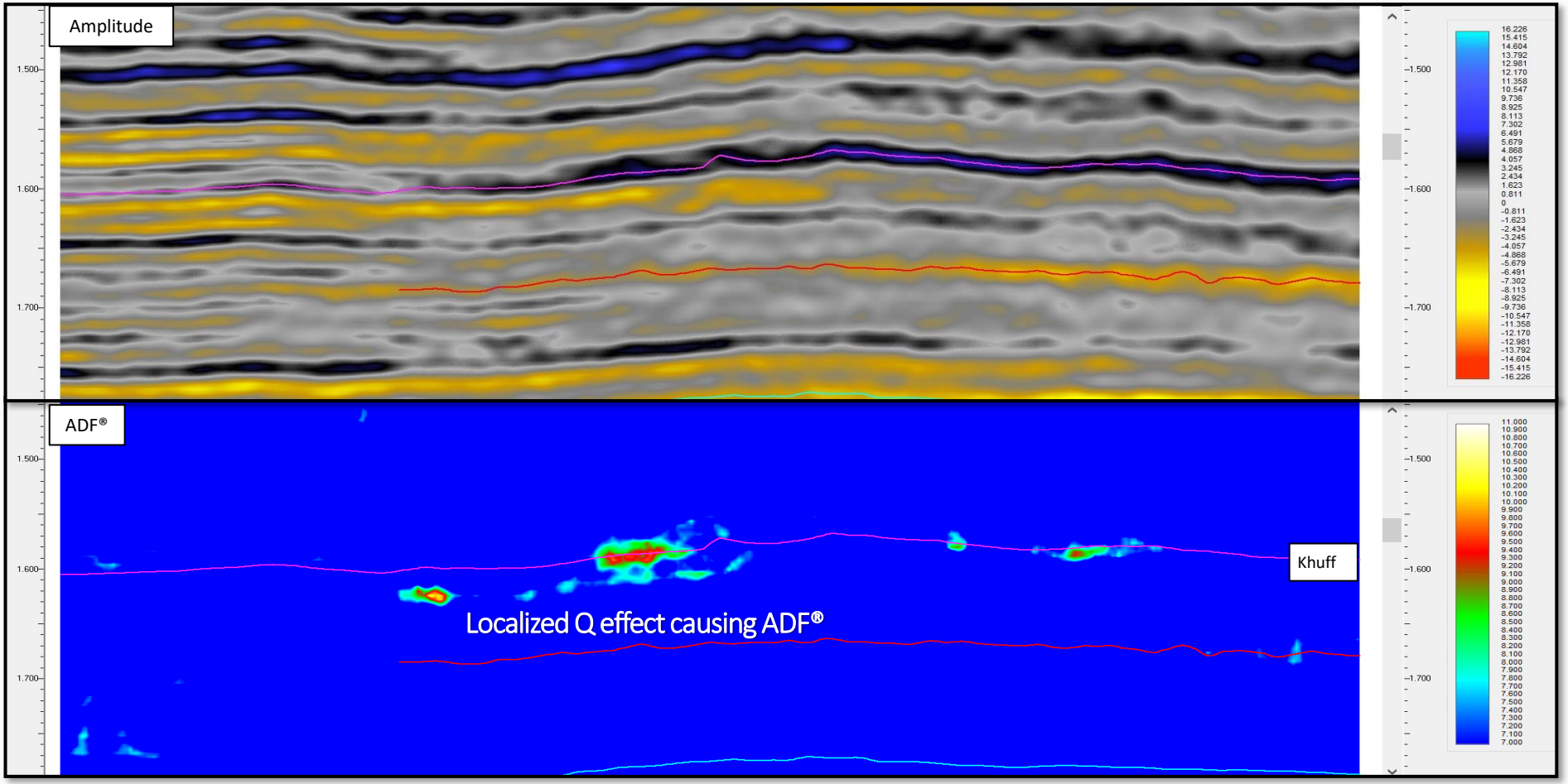
# Inter-Granular Friction Causes Macro Q




ADF® does *not* measure Macro Q

ADF® measures anomalous localized Q effects that cause frequency dependent velocity and therefore frequency dependent reflection coefficients

Hydrocarbons sometimes cause stronger local Q effects due to their high relative perm


Amplitude
1.500
1.600
1.700
16.226
15.415
14.604
13.792
12.981
12.170
11.358
10.547
9.736
8.925
8.113
7.302
6.491
5.679
4.868
4.057
3.245
2.434
1.623
0.811
0
-0.811
-1.623
-2.434
-3.245
-4.057
-4.868
-5.679
-6.491
-7.302
-8.113
-8.925
-9.736
-10.547
-11.358
-12.170
-12.981
-13.792
-14.604
-15.415
-16.226
ADF®
Khuff
Localized Q effect causing ADF®
11.000
10.900
10.800
10.700
10.600
10.500
10.400
10.300
10.200
10.100
10.000
9.900
9.800
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8.000
7.900
7.800
7.700
7.600
7.500
7.400
7.300
7.200
7.100
7.000

# Apex Spectral Technology

- **Founded in 2002, in business 22 years**
- **Invented ADF® fluid mobility imaging from seismic data**
- **Patented ADF®**
- Performed ADF® projects worldwide
- **Published ADF® proof of concept results in a paper sponsored by Shell at 2021 EAGE**
- **Published ADF® theory at Image 2024**

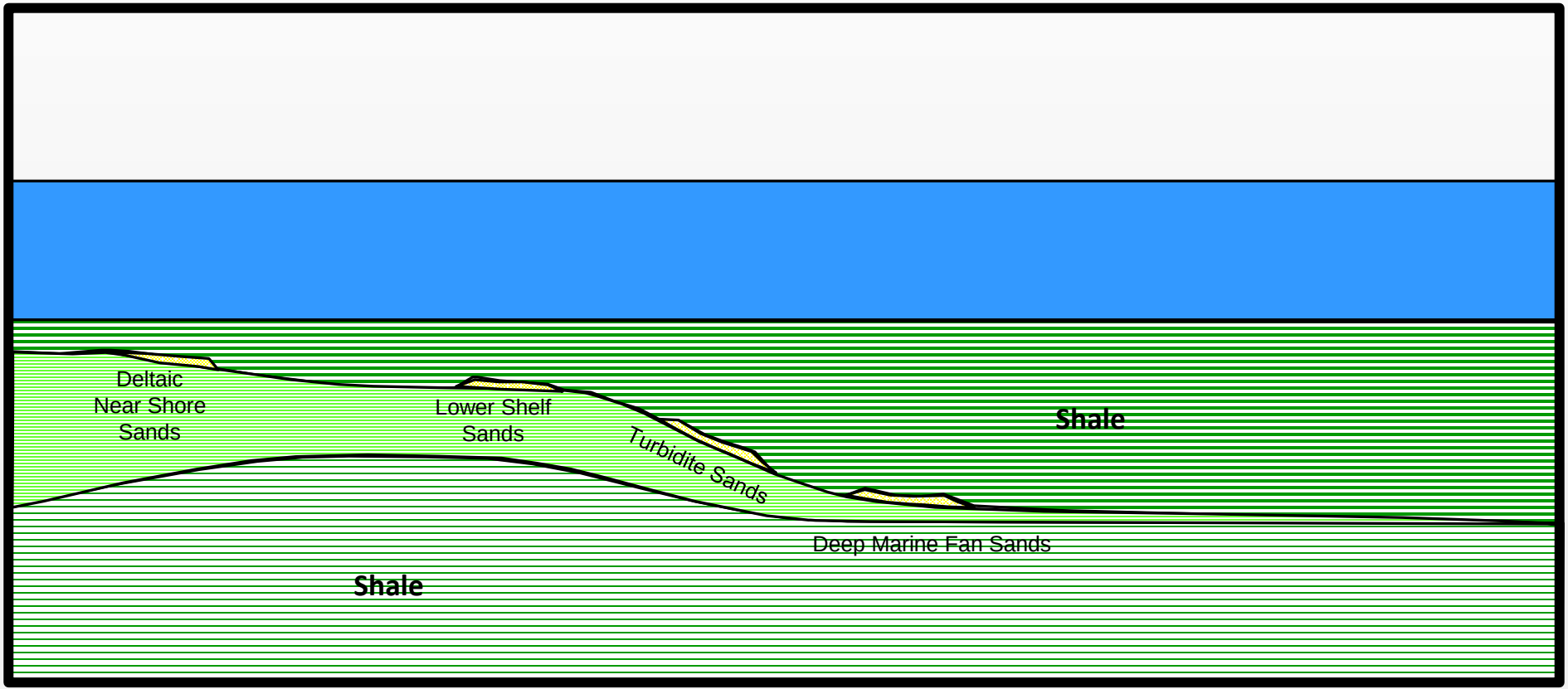
# ADF®

- **ADF® measures fluid movement due to the passing seismic wave**
  - **permeability**
  - **relative permeability**
  - **Thickness**

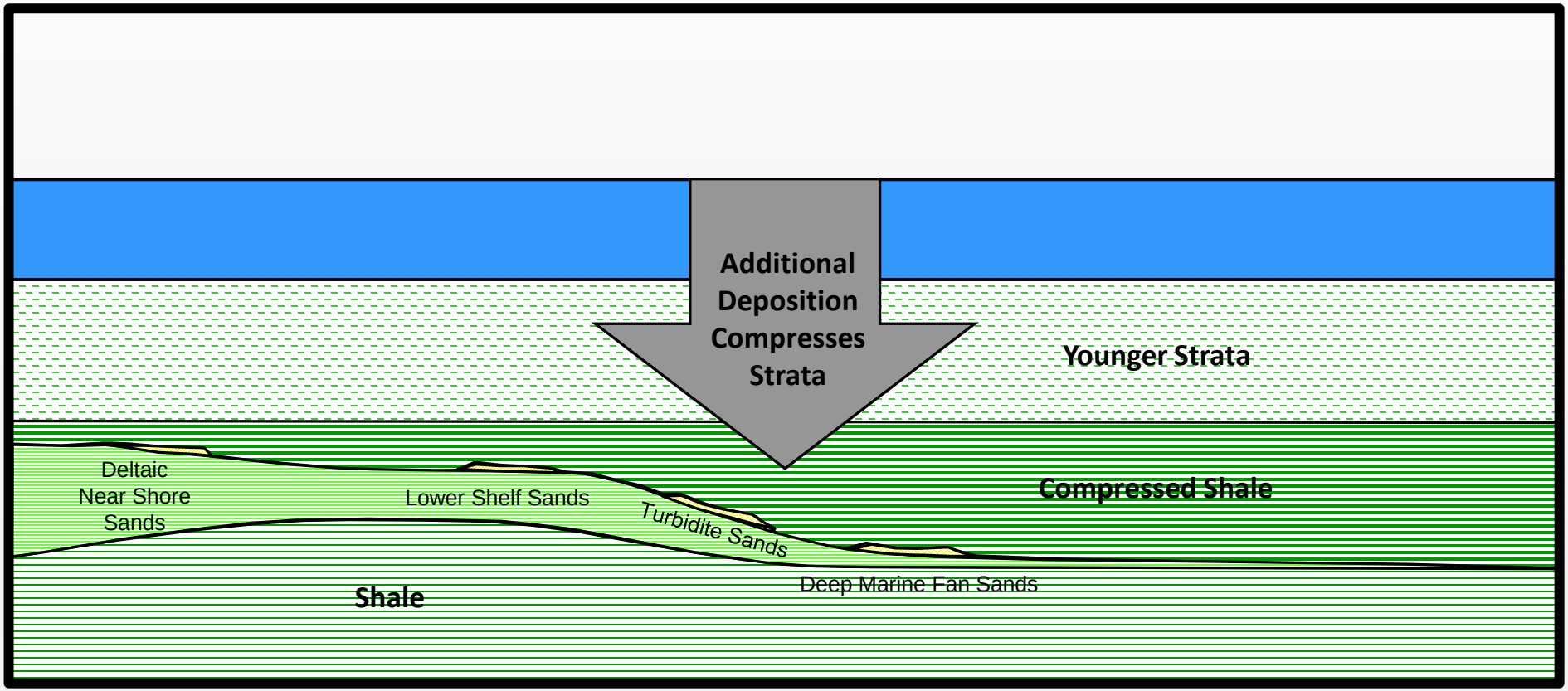
- **ADF® is *independent* of amplitude**

- ***ADF® uses only seismic* as input, so well data is not required**

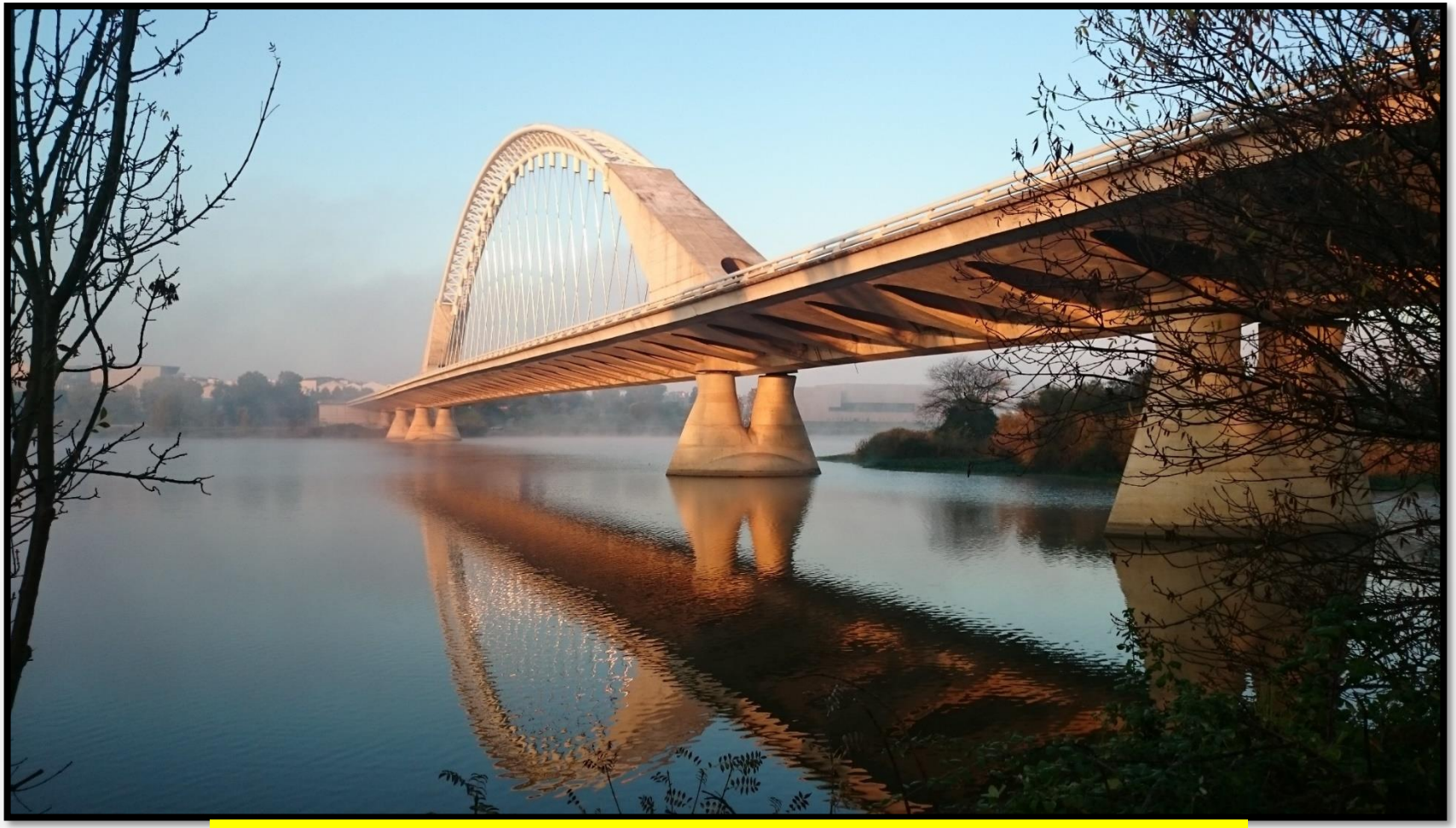
# Young sands are commonly ***slower*** than shale cap rock, add gas, and you get bright spots & AVO



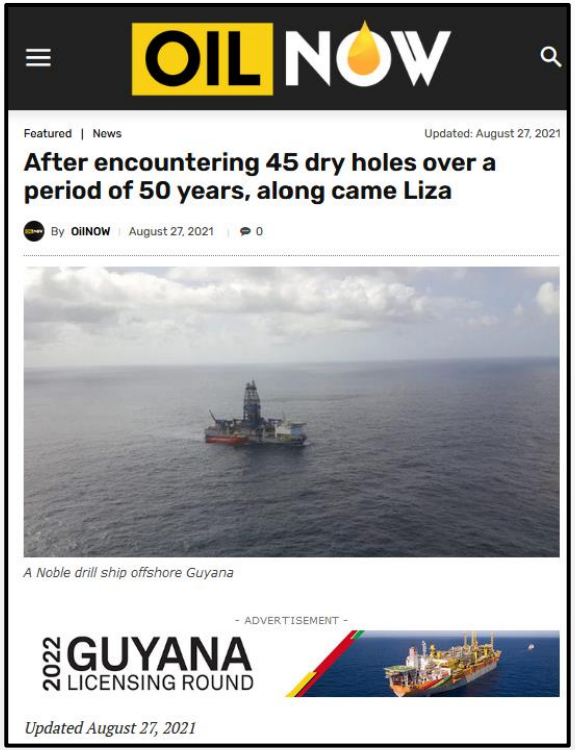
# Older sands are commonly *not slower* than shale caprock & bright spot/AVO become ineffective




**Velocity contrast between sand and shale is reduced with compaction**



**Bridge building technology is mature, bridges rarely fall down**



OIL NOW

Featured | News

Updated: August 27, 2021

After encountering 45 dry holes over a period of 50 years, along came Liza

By OilNOW | August 27, 2021 | 0

A Noble drill ship offshore Guyana

- ADVERTISEMENT -

2022 GUYANA LICENSING ROUND

Updated August 27, 2021

**Before 2015, offshore Guyana *45* wells were drilled without a commercial discovery.**

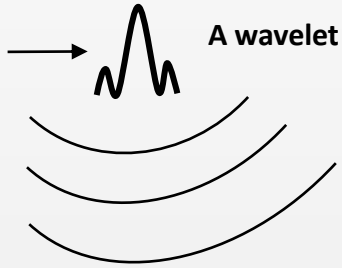
- **In a prolific basin, 45 times in a row some combination of amplitude, AVO and EI (industry mainstay tools) didn't work.**
- **As this was a frontier basin, well data was sparse so seismic was the primary exploration tool.**
- **Shell relinquished the Stabroek block before Exxon picked it up.**
- **Exxon did not want to drill Liza, the Stabroek discovery well, but it was a commitment well and Exxon could not get out of it.**

***The industry's track record speaks for itself, seismic theory is immature***

# What is Seismic Data?

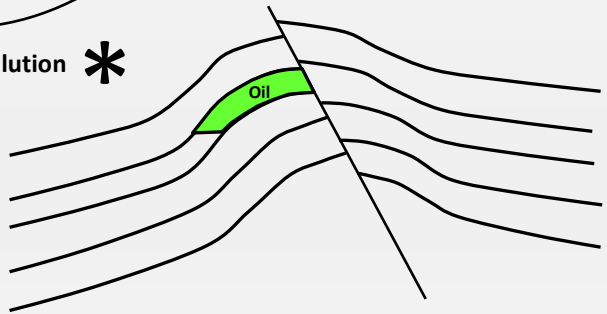
Hitting a *range* of keys creates a wavelet

Wavelet



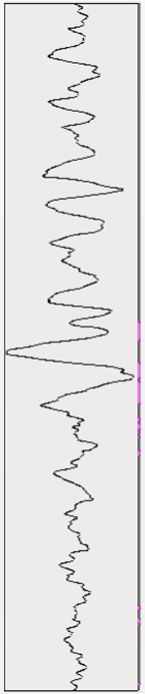
A wavelet contains a ***range*** of frequencies

Convolution *




Geology includes Reservoirs with Perm and Relative Perm

=




**Seismic is composed of two parts.**

**Is it**

***a wavelet*** **& geology**

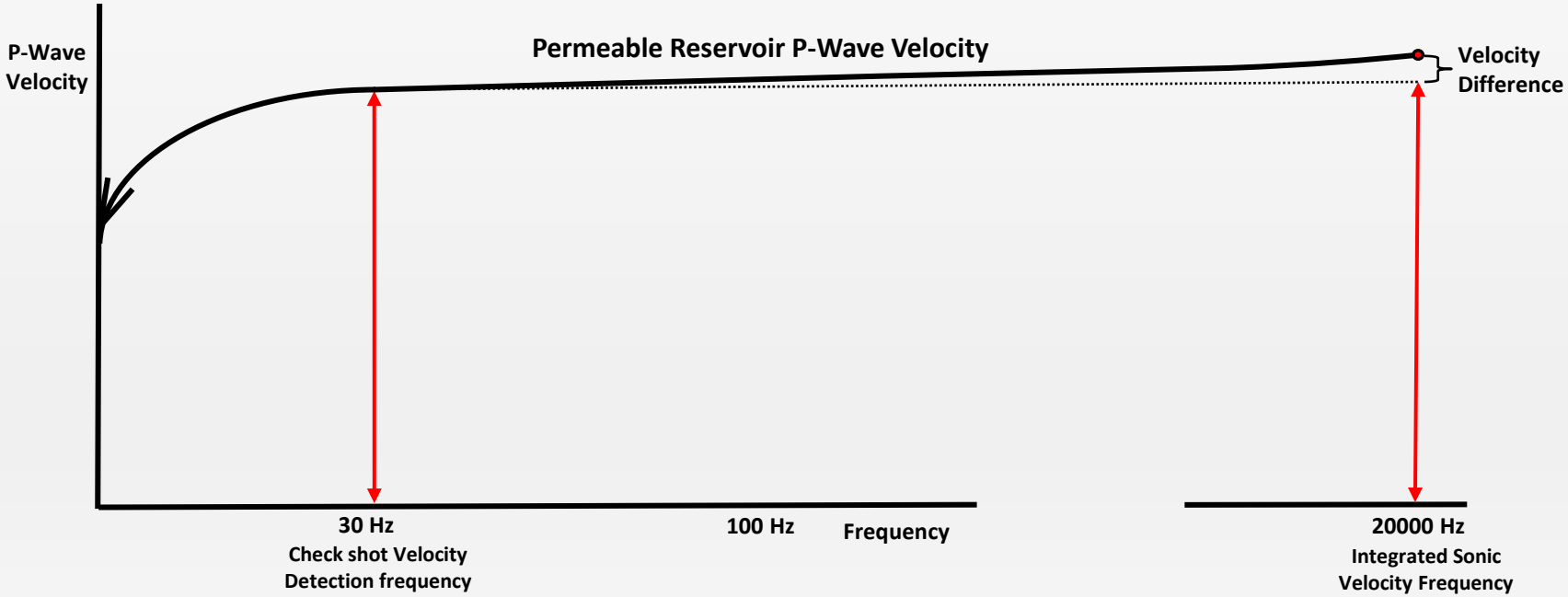
**or**

***wavelets*** **& geology?**

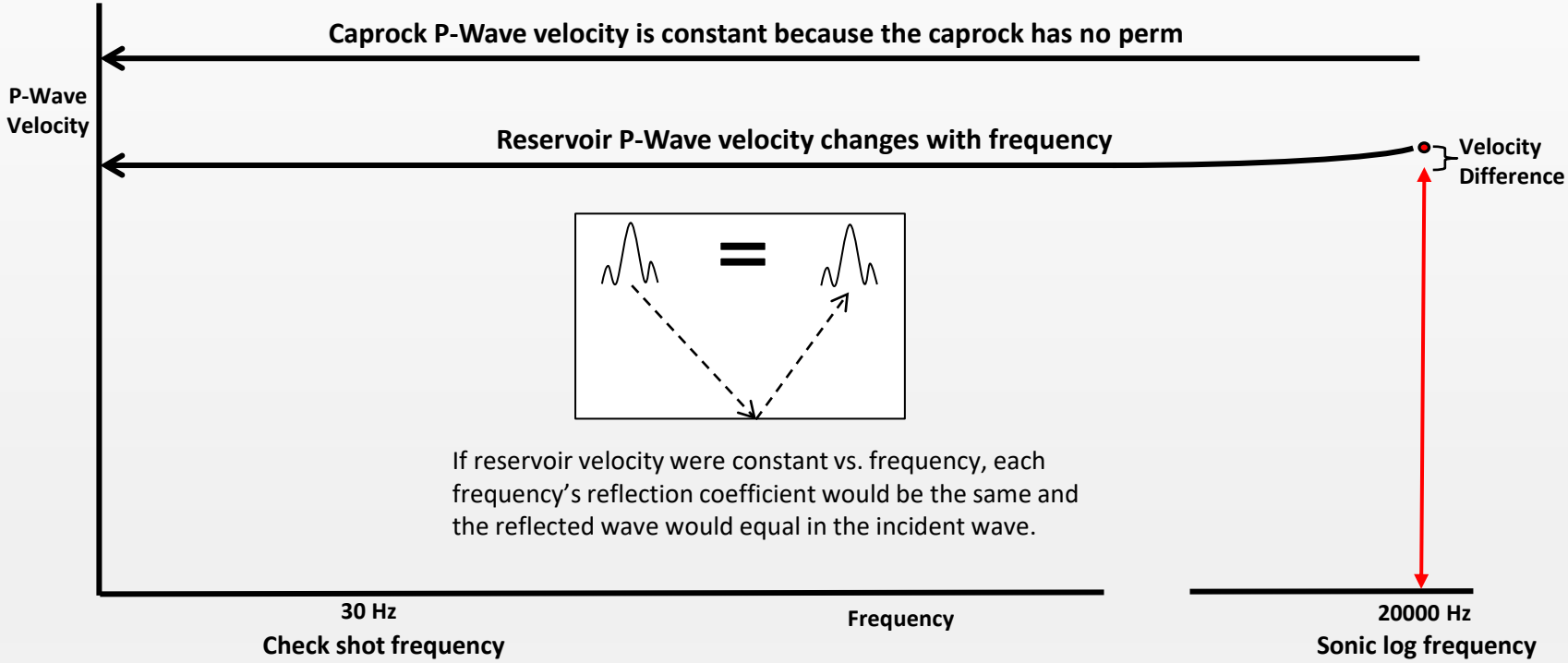
# Frequency Dependent Seismic Velocities

**In 1975 J. E. White explained the need to check shot correct sonic logs, but in the first sentence of the first paragraph White also wrote…**

***"Calculations for an unconsolidated sand with partial gas saturation show a 20 percent increase in compressional wave velocity between 1 and 100 Hz"***

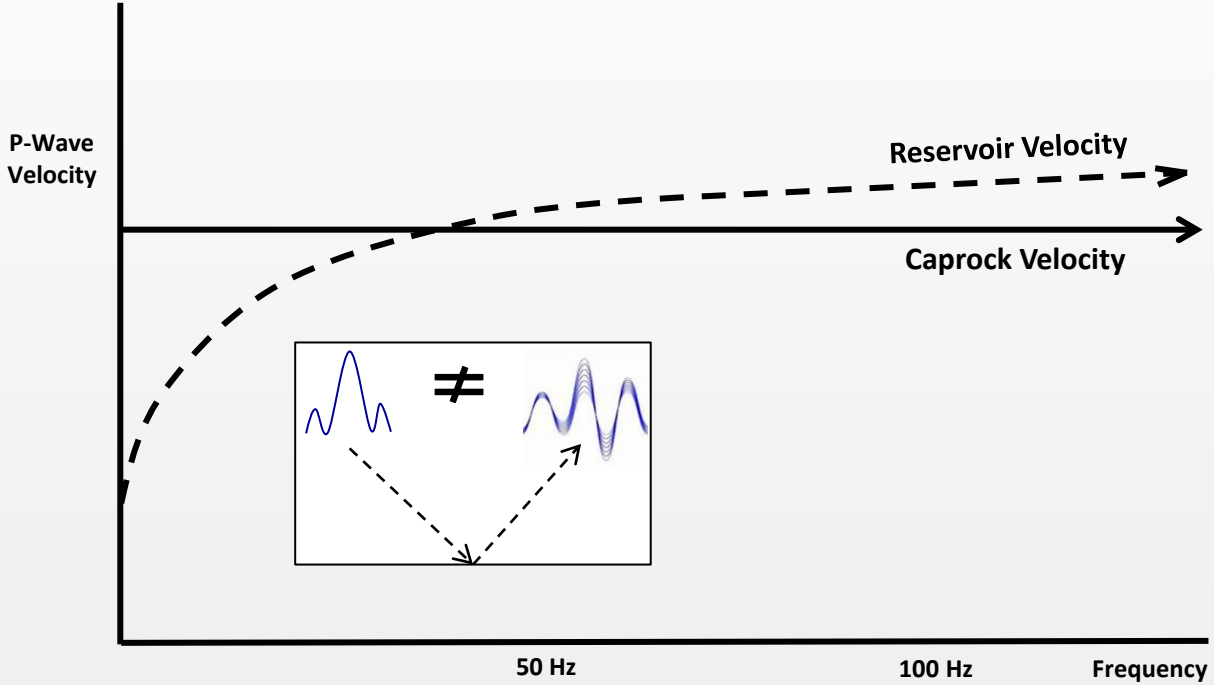


# The industry made a first principal simplification in 1975 by assuming no dispersion




**No dispersion mandated a constant wavelet**

# Permeability Causes Pronounced Dispersion

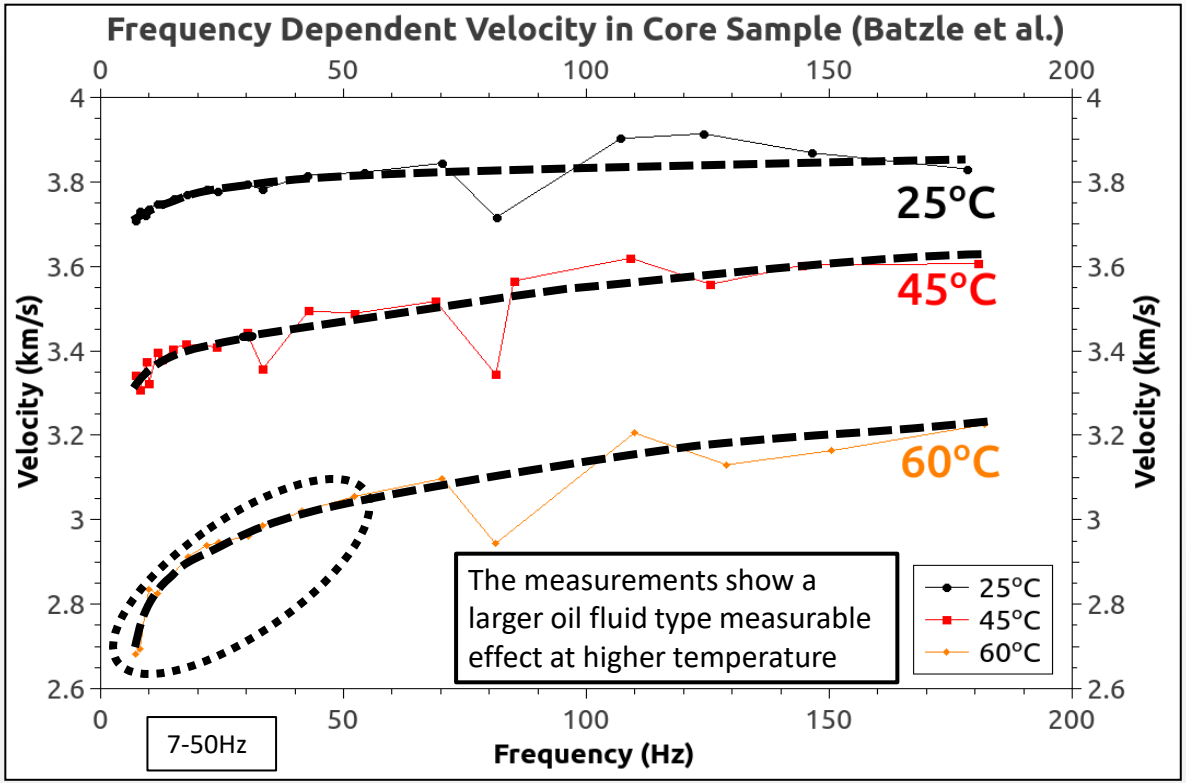



**Dispersion causes dynamic wavelets**

# Batzle Measured Dispersion in a Laboratory

"Fluid mobility and frequency-dependent seismic velocity", Michael Batzle, et al; 2006 in the Geophysics Vol 71.

The largest drop in P wave velocity occurs between 5 and 30 Hz.



SEG | AAPG image
International Meeting for Applied Geoscience & Energy

## Apex Spectral Technology Paper published by IMAGE August 29, 2024

**“Hydrocarbon exploration method based on spectral analyses of reflected seismic waves with an introduction to class A, B and C P-Wave dispersion”**

*Apex Spectral references papers by Dr. White (who referenced Biot), Carcione and Picotti, that discuss seismic dispersion in a fluid filled reservoir. Dr. Batzle laboratory work that supports their seismic dispersion work is also discussed.*

*Extrapolating on this work, Apex Spectral explains that dispersion inside the seismic bandwidth means permeable layers cause frequency dependent reflection coefficients, which in turn cause measurable changes to the reflected wavelets. Since hydrocarbons typically have anomalous fluid mobility, analyses of the reflected wavelets may reveal not only reservoir quality but also hydrocarbon charge.*

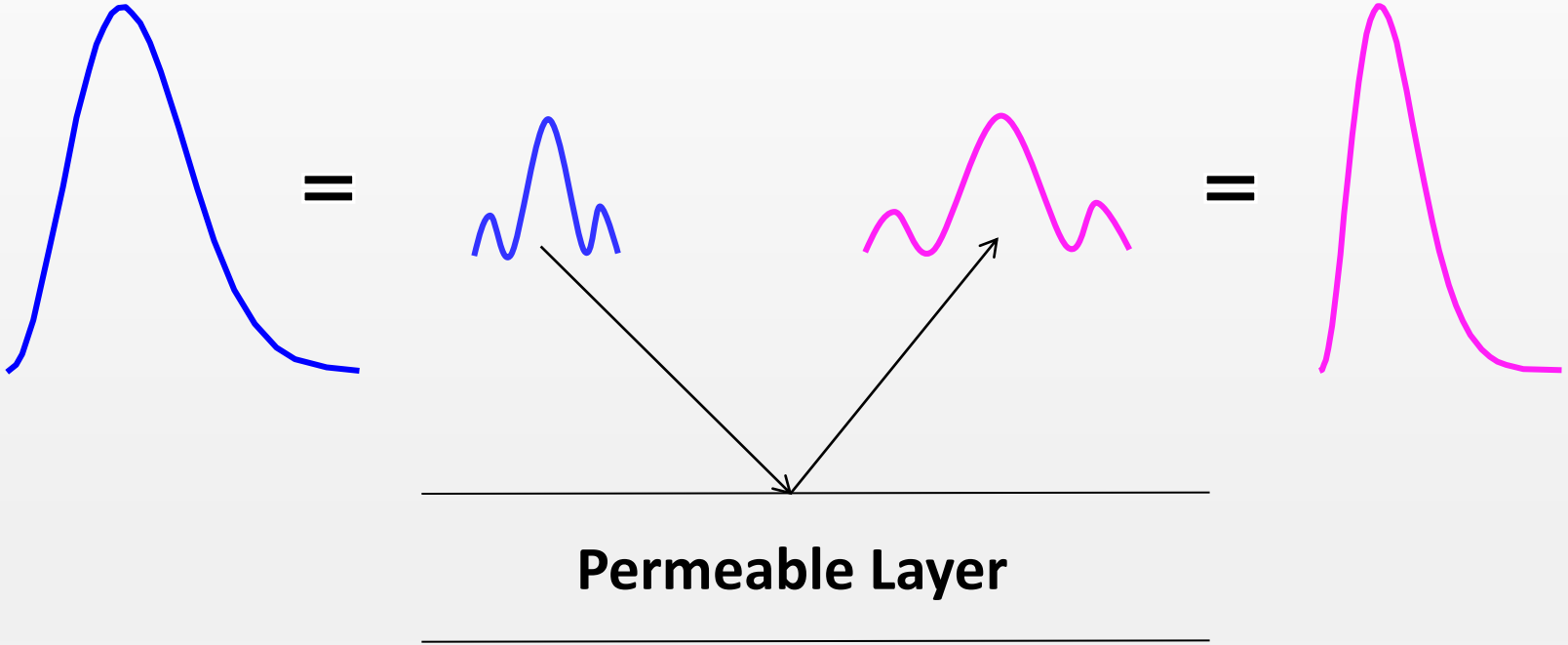
*Apex Spectral also reviews their proprietary ADF® imaging technology and explains three different dispersion settings referred to as Class A, B and C ADF®, which are analogous to Class I, II and III AVO.*

Wavelet In Frequency Domain

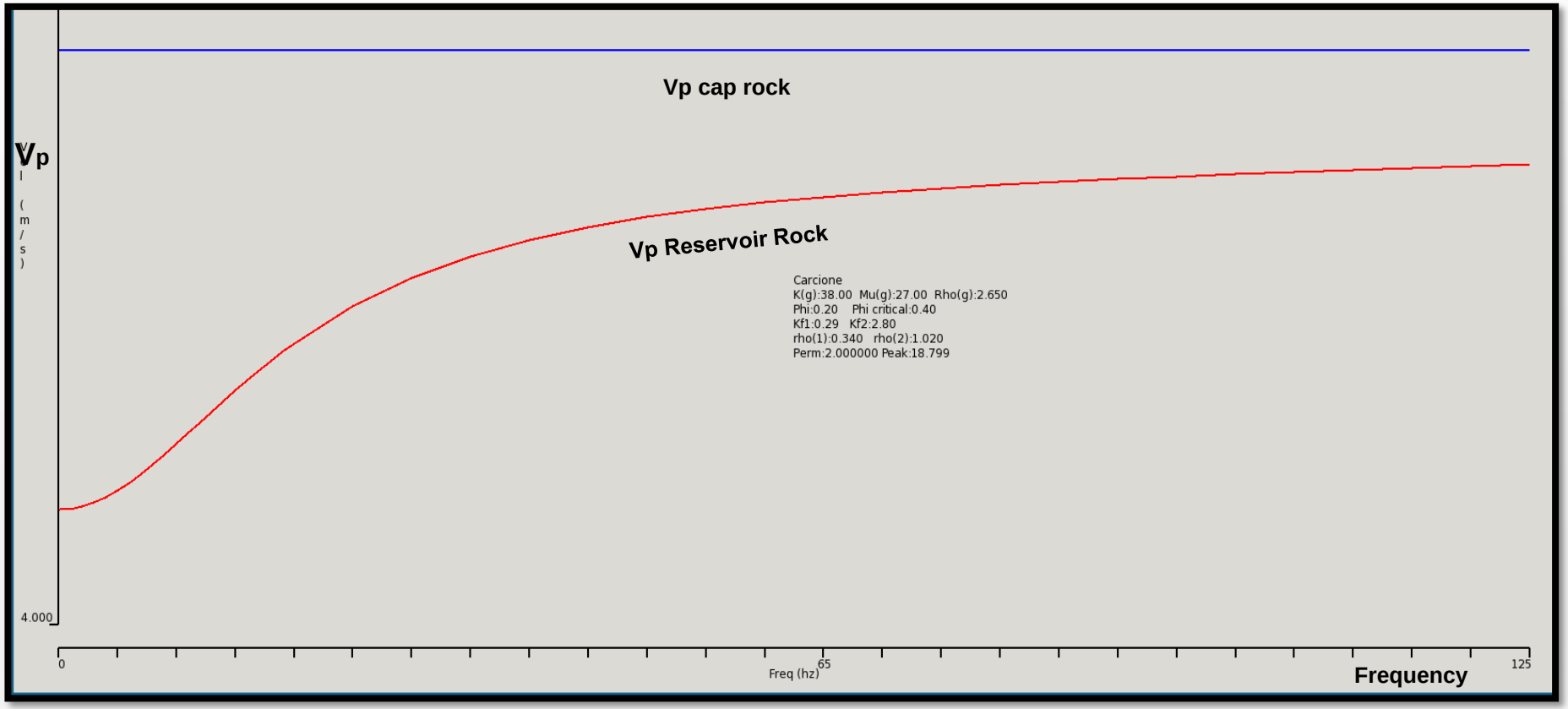
Wavelet In Time Domain

Time Domain Stretch

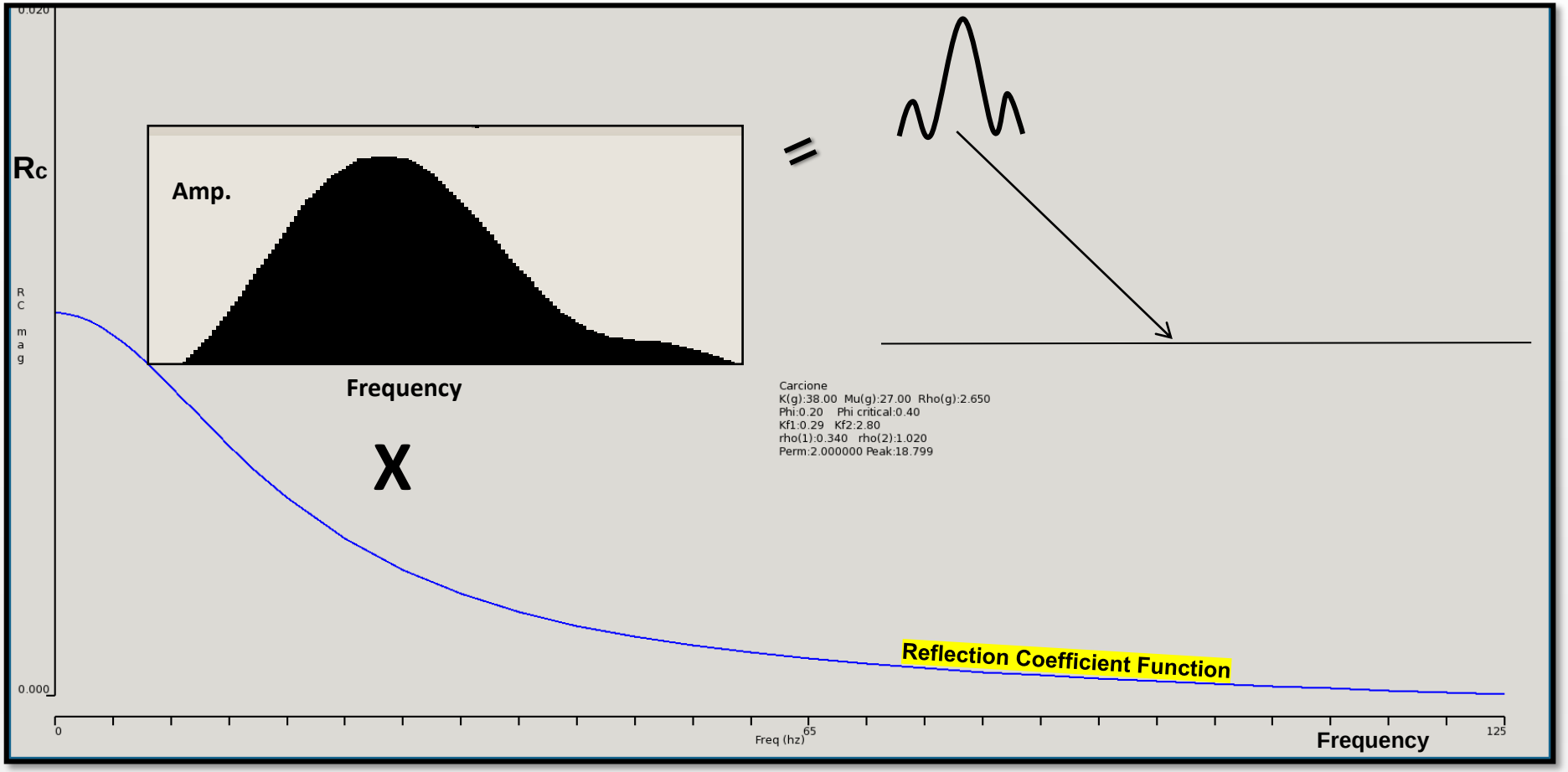
Frequency Domain Compression

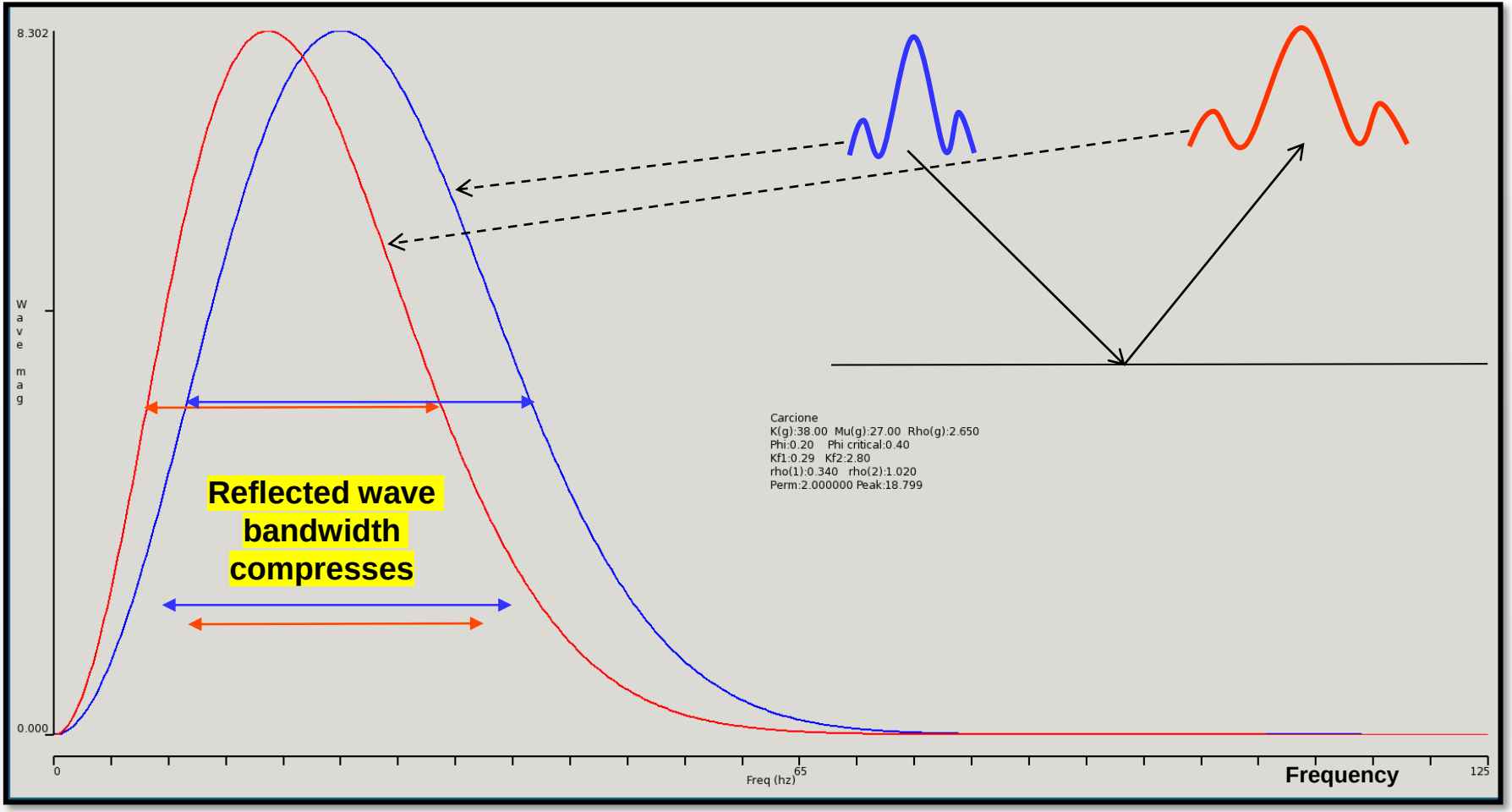


# Frequency Dependent Velocity Means Freq. Dependent $R_c$

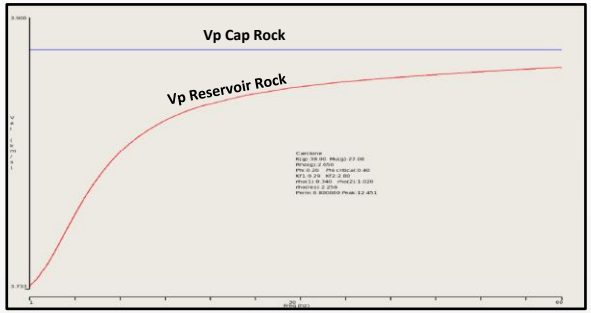



2006, Carcione & Picotti, Italy National Institute of Geophysics

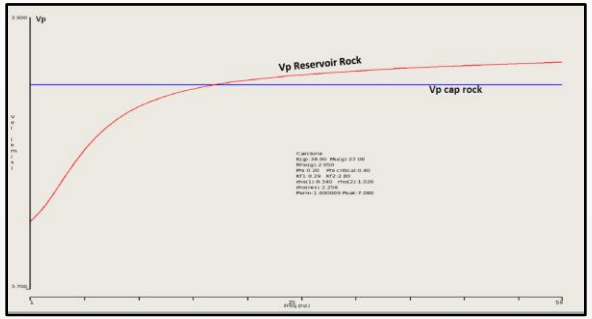

Rc
0.020
0.000
R
C
m
a
g
Amp.
Frequency
X
=
Carcione
K(g):38.00 Mu(g):27.00 Rho(g):2.650
Phi:0.20 Phi critical:0.40
Kf1:0.29 Kf2:2.80
rho(1):0.340 rho(2):1.020
Perm:2.000000 Peak:18.799
Reflection Coefficient Function
0
65
125
Freq (hz)
Frequency


AMPLITUDE
8.302
Wave mag
0.000
Reflected wave bandwidth compresses
Carcione
K(g):38.00 Mu(g):27.00 Rho(g):2.650
Phi:0.20 Phi critical:0.40
Kf1:0.29 Kf2:2.80
rho(1):0.340 rho(2):1.020
Perm:2.000000 Peak:18.799
0
65
125
Freq (hz)
Frequency

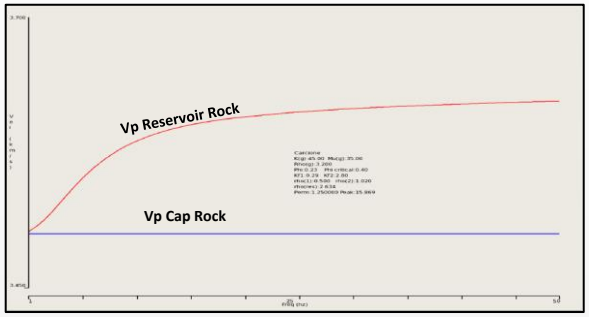
Class III AVO – reservoir is slower than above layer



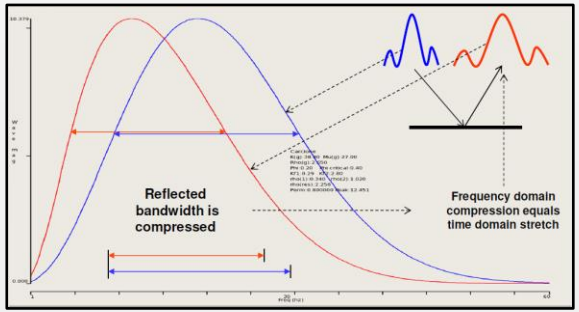

Class II AVO – reservoir velocity is close to that of above layer



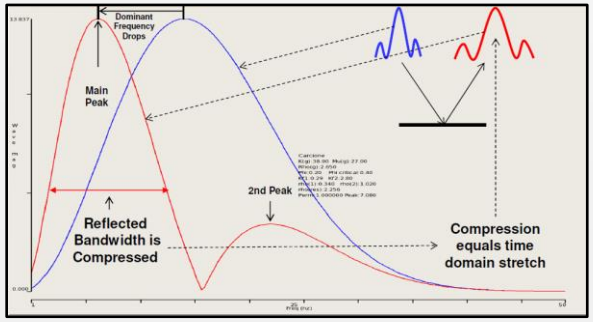

Class I AVO – reservoir velocity is faster than of above layer



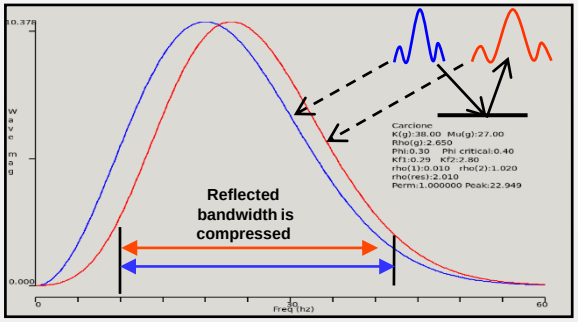

DF decrease with dispersion




Depending on crossover point the DF will increase or decrease



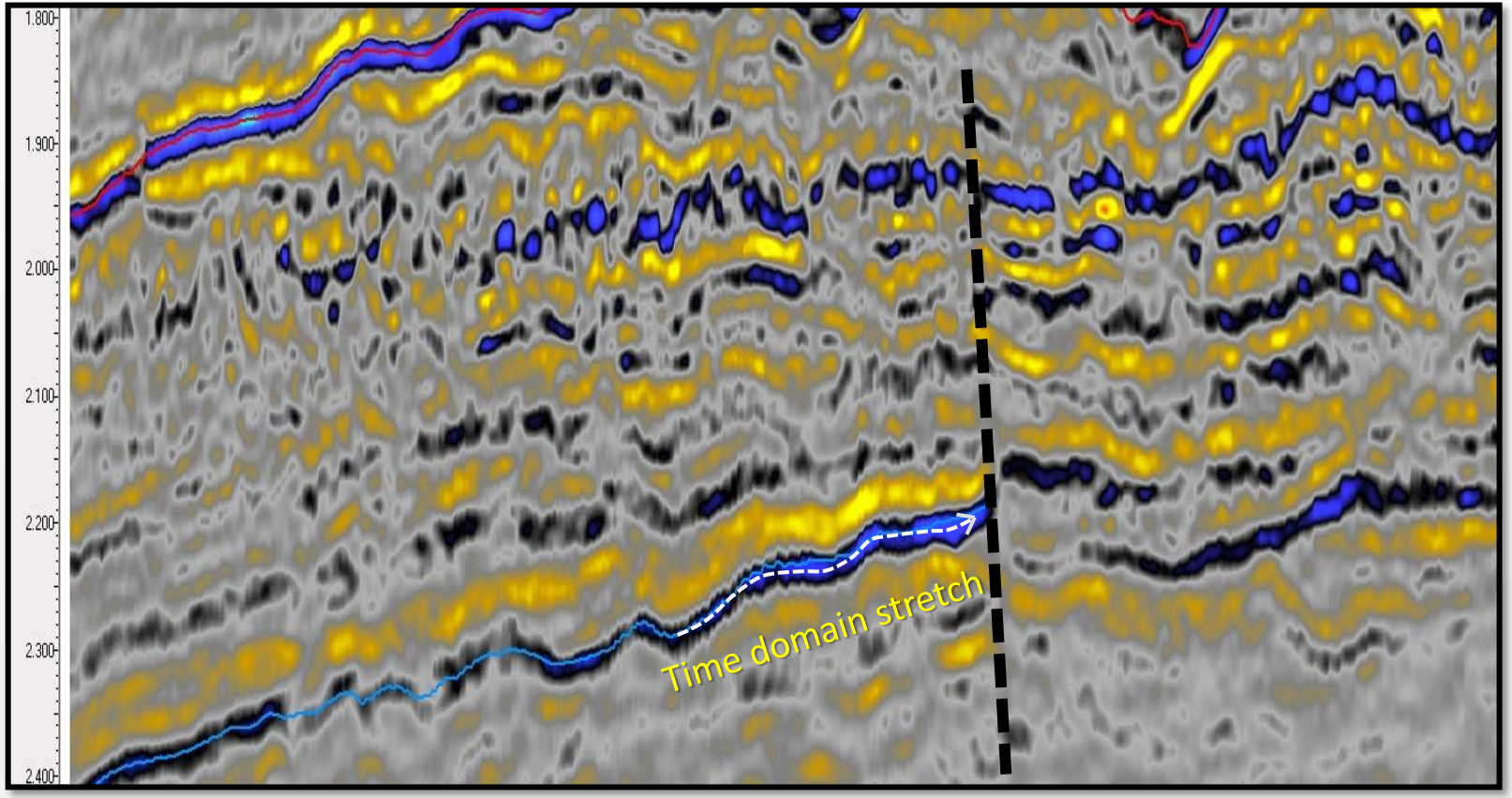

DF increases with dispersion

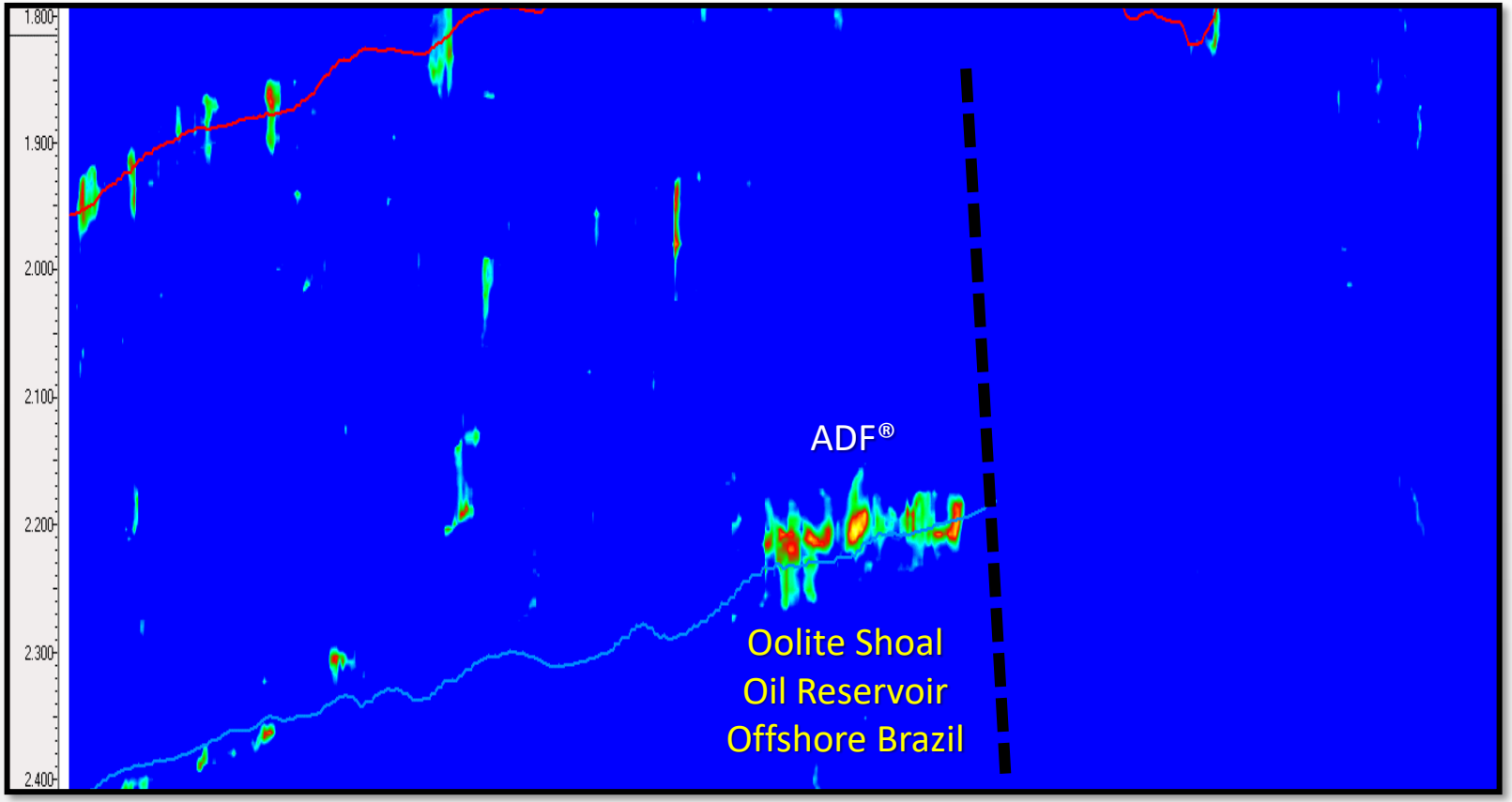



**Class C ADF®**

**Class B ADF®**

**Class A ADF®**


1.800
1.900
2.000
2.100
2.200
2.300
2.400
Time domain stretch


1.800
1.900
2.000
2.100
2.200
2.300
2.400
ADF®
Oolite Shoal
Oil Reservoir
Offshore Brazil

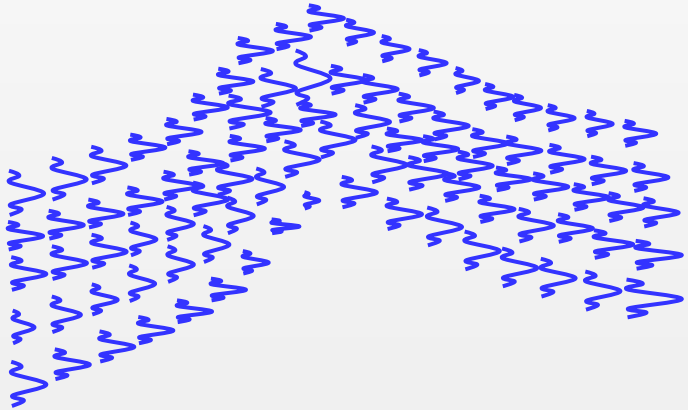
## ADF® is the opposite of inversion

**Unlike inversion ADF® is calculated without using well data**

**One wavelet derived using well data**

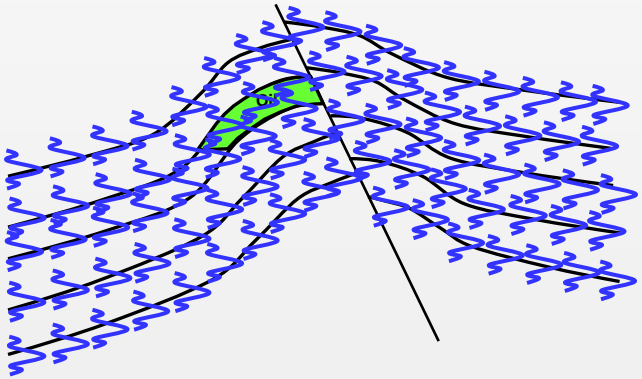
***Or***

**ADF® calculates wavelets without using well data**

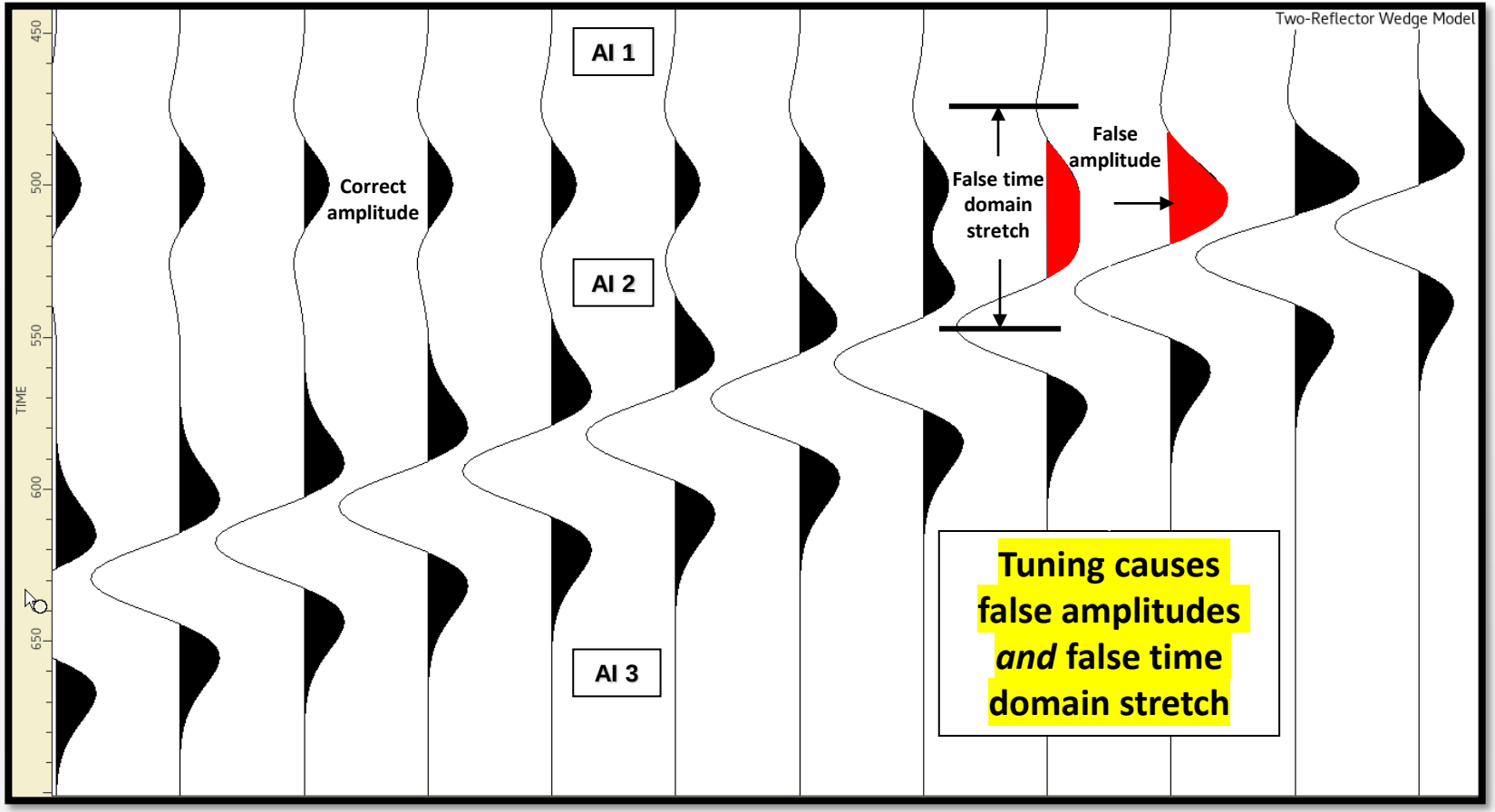


**&**

**Geology**



# Two-Reflector Wedge Model




Acoustic Impedance ("AI") = P wave velocity * density

# Push-Back - Industry Tools Assuming a Constant Wavelet

- Spiking & Gap Deconvolution
- Amplitude Q compensation
- Elastic Impedance Inversion
- Whitening

# Typical Seismic Archive Points For Land & Marine Data

## Land Data

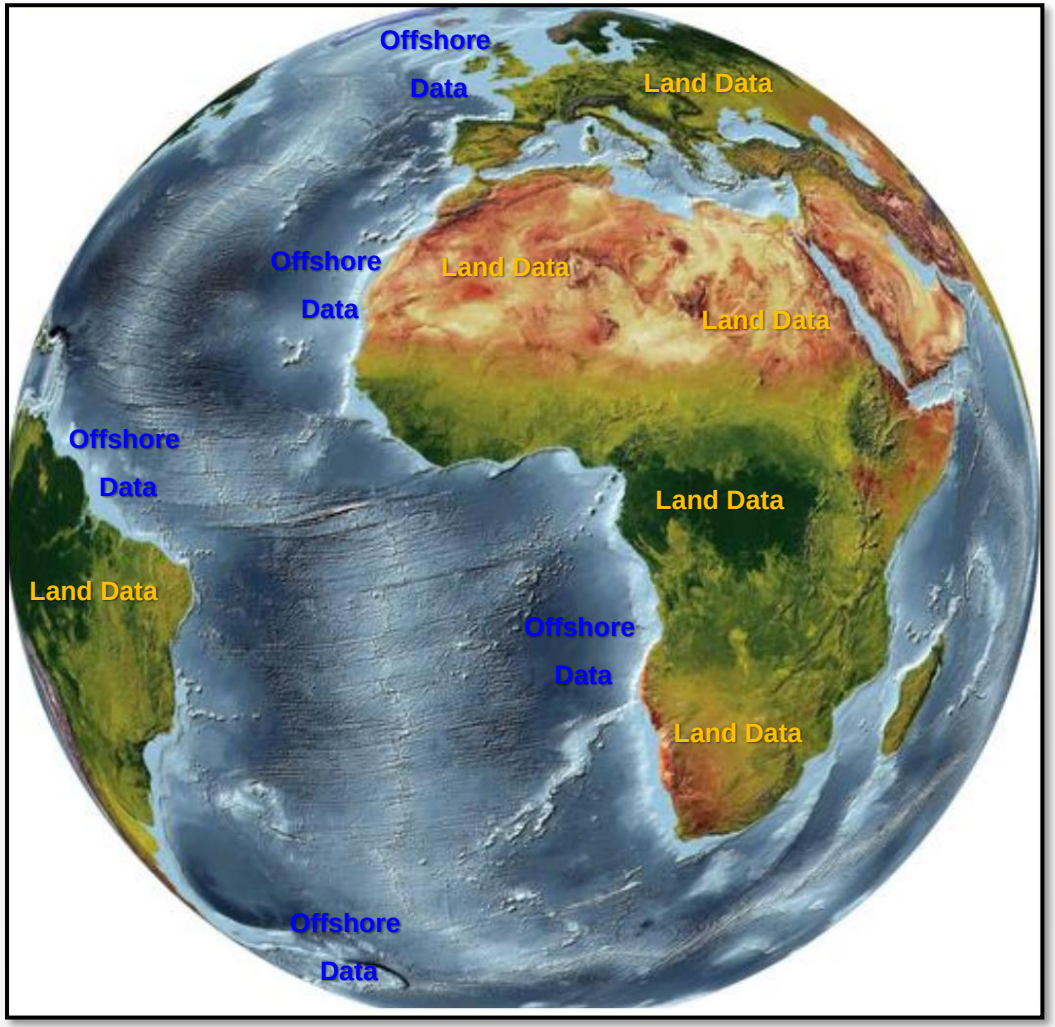
Field Data > Spiking Deconvolution > Migration > EI

Non-whitened Archive Point

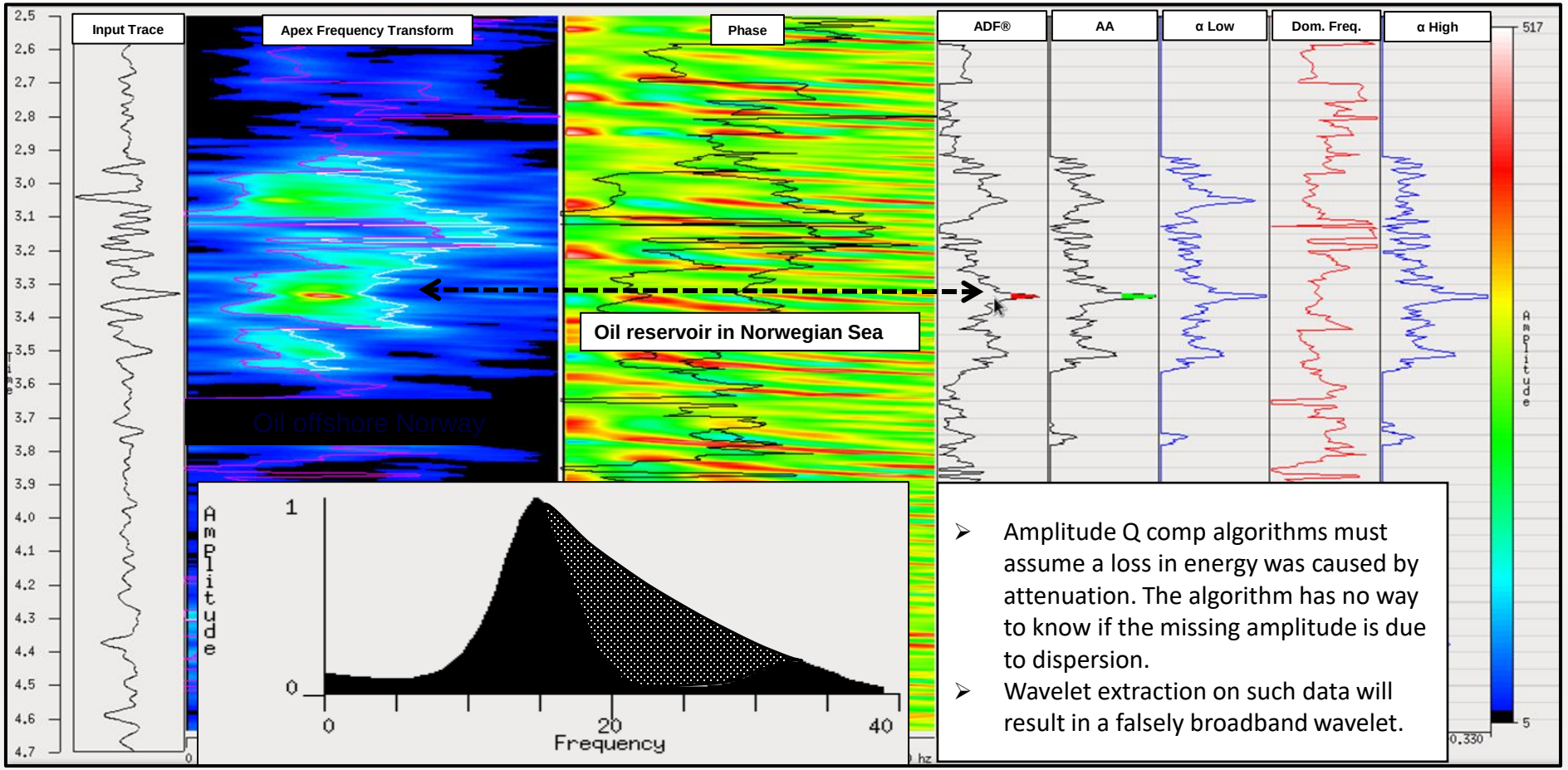
## Offshore Data

Field Data > Migration > Amplitude Q Comp > EI

Non-whitened Archive Point

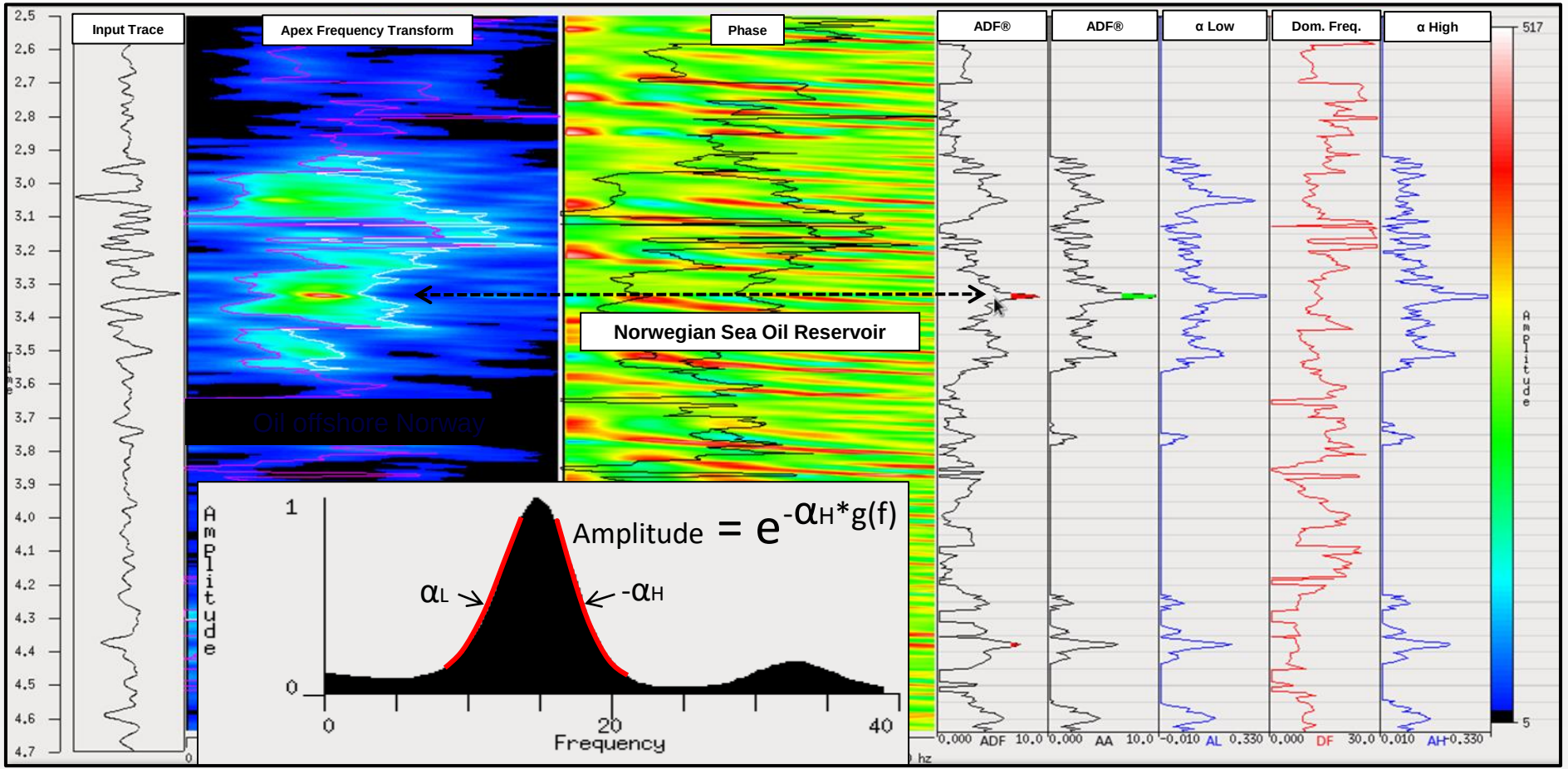


# Amplitude Q Compensation Plus Inversion Can Cause Dry Holes

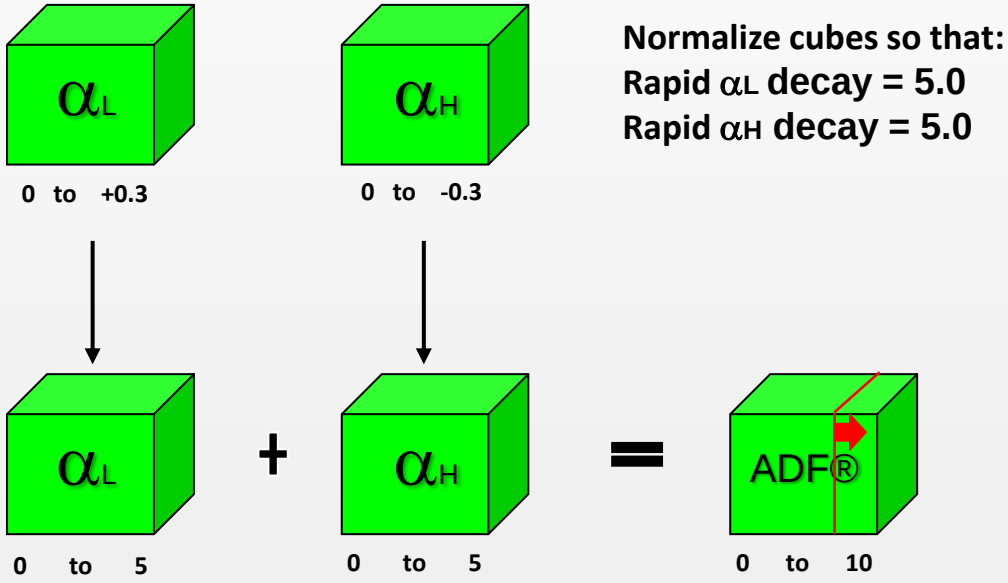



- Amplitude Q comp algorithms must assume a loss in energy was caused by attenuation. The algorithm has no way to know if the missing amplitude is due to dispersion.
- Wavelet extraction on such data will result in a falsely broadband wavelet.

# Dispersion causes spectral compression

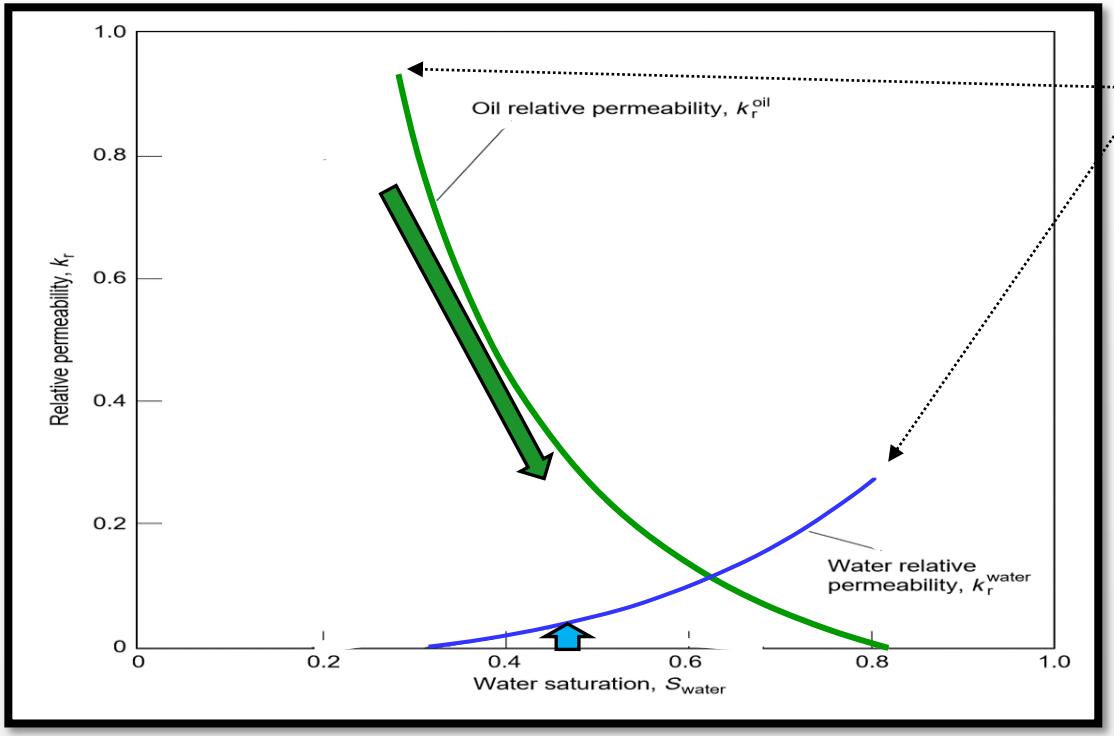


# Generating “ADF®” Fluid Mobility Cubes




**An ADF® cube is computed by summing the two alpha cubes to get one cube scaled 0 to 10**

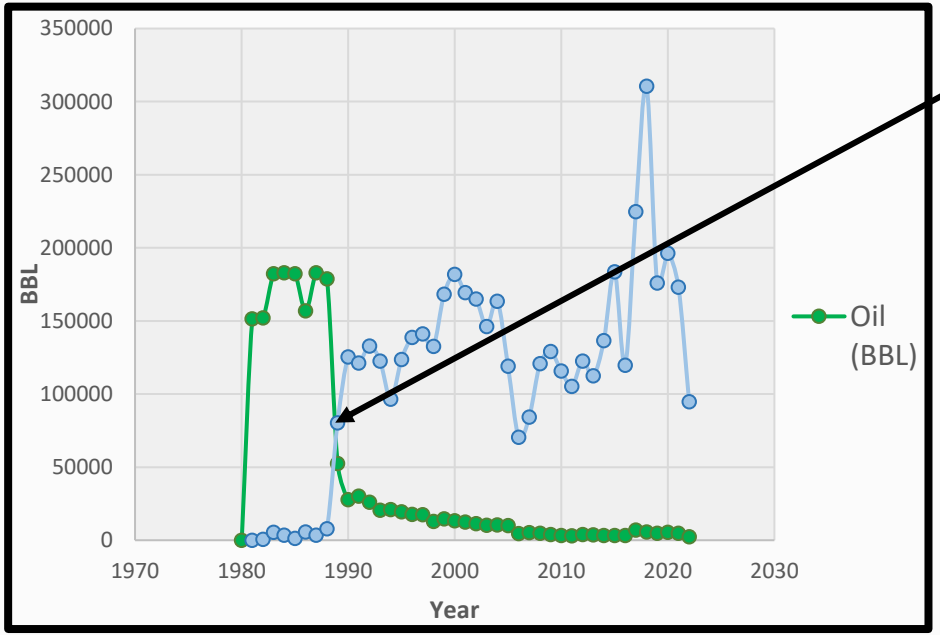
**Large relative permeability drop as a reservoir is produced causes *large* ADF® 4D effect**



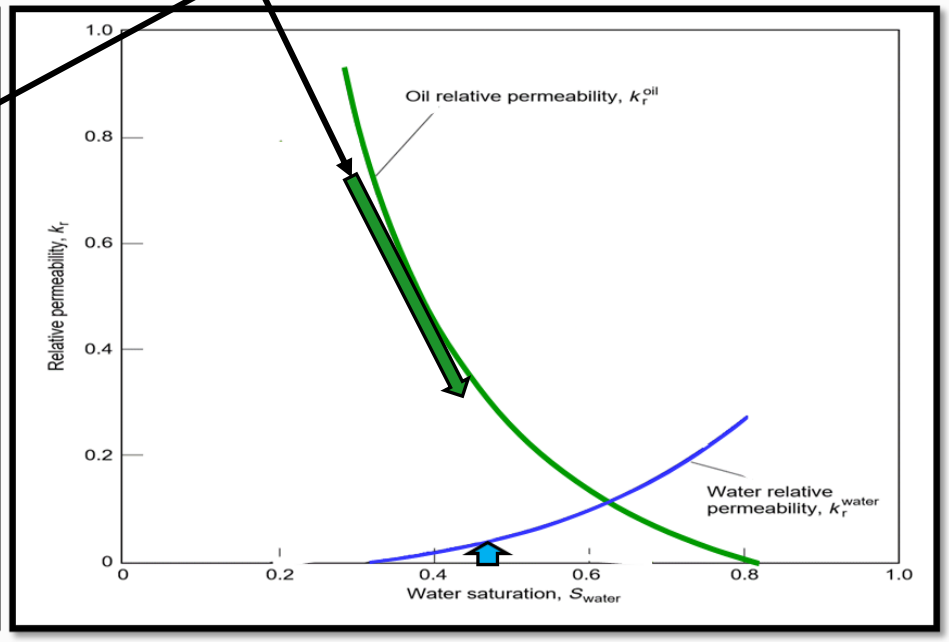

**ADF® can be a DHI because the relative permeability of oil in water wet reservoirs is typically much higher than brine**

Toward Improved Prediction of Reservoir Flow Performance; John J. Buckles, Randy D. Hazlett, et al

**Normal pressure well with a strong water drive**




**The drop in oil production is tied to the drop in relative permeability.**

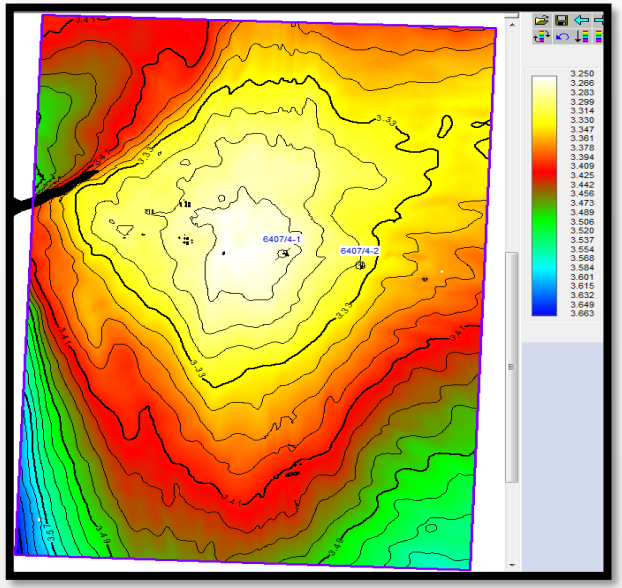


# Patents Prove Technology is Unique

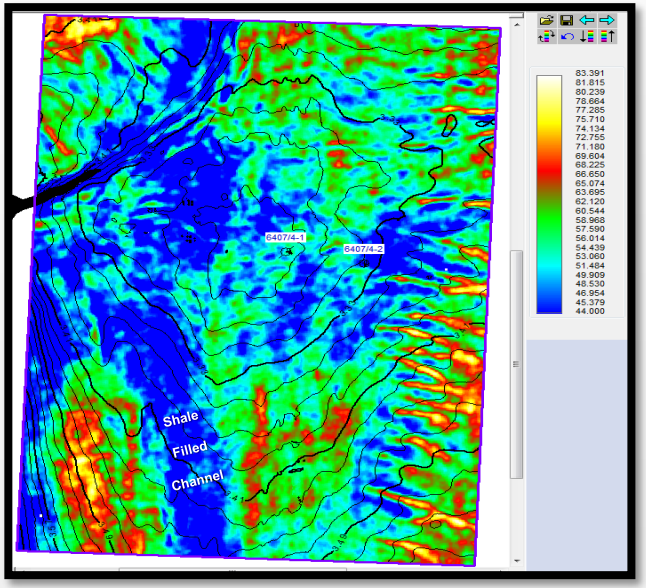
- USA Patent No. 7,243,029 B2
- USA Patent No. 7,876,643 B2
- USA Patent No. 9,551,799 B2
- European Patent No. 1664845
- European Patent Application Number 11843437.2
- Australia Patent No. 2,004,267,449
- Australia Patent No. 2,008,242,961
- Australia Patent No. 2,015,202,249
- Australia Patent No. 2,008,305,385
- Canada Patent No. 2,700,627
- Canada Patent No. 2,818,641
- Japan Patent No. 5,355,575

# ADF® Removes Tuning Effects

**Time Structure**

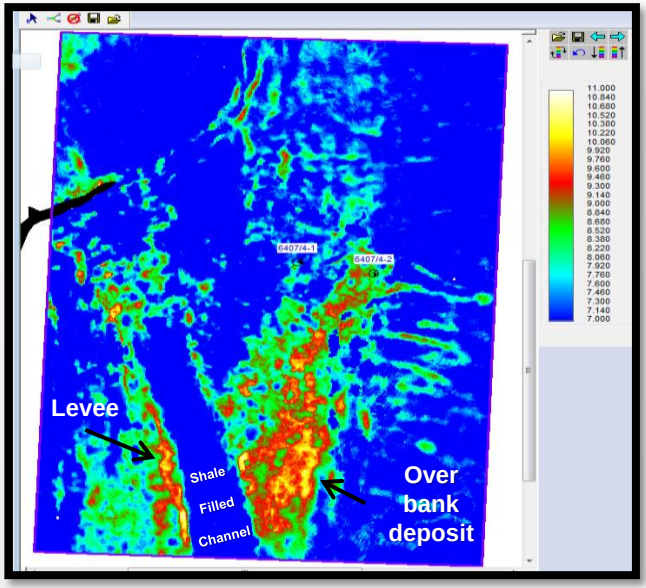



**Amplitude**




**Tuning blurs amplitude & geology**

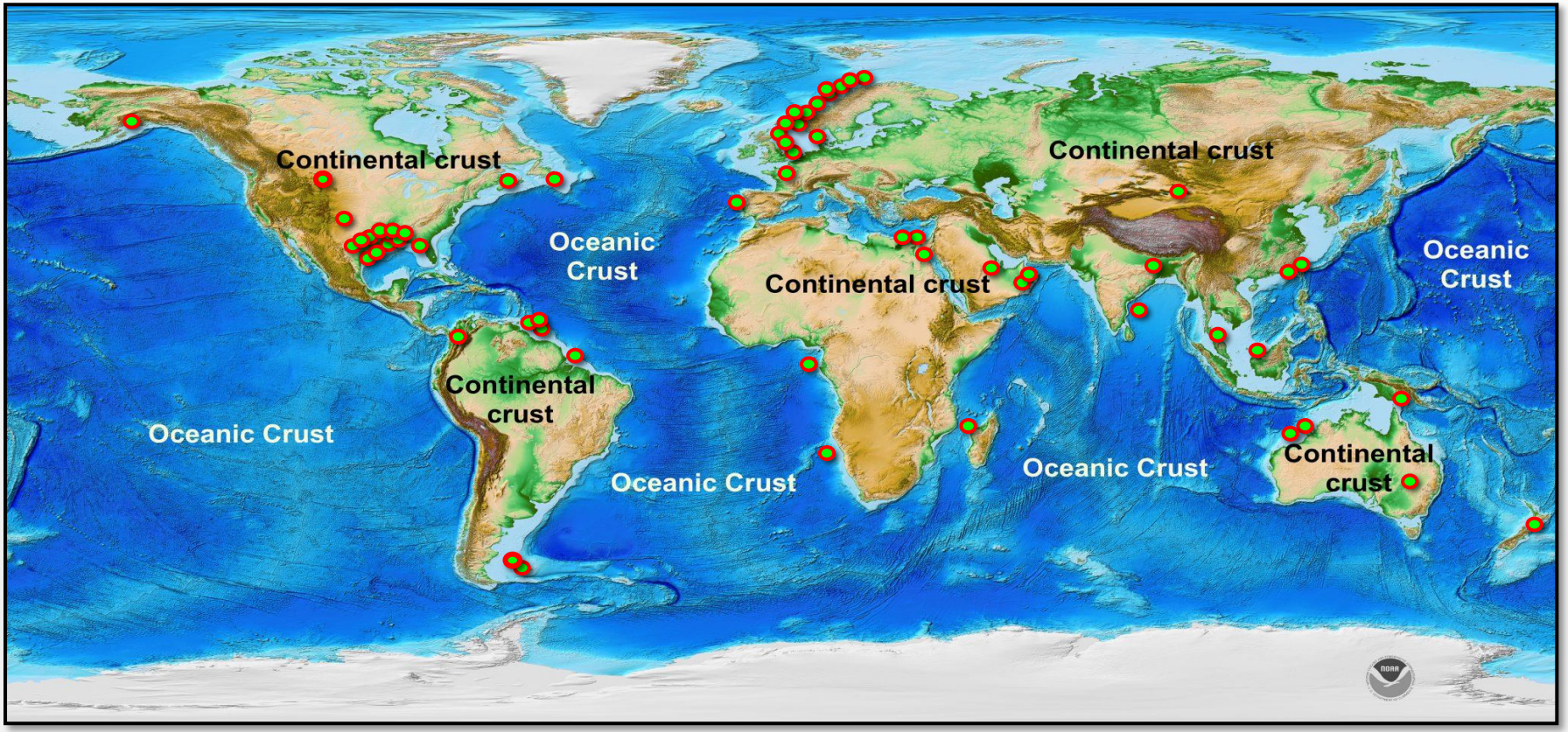
**ADF®**

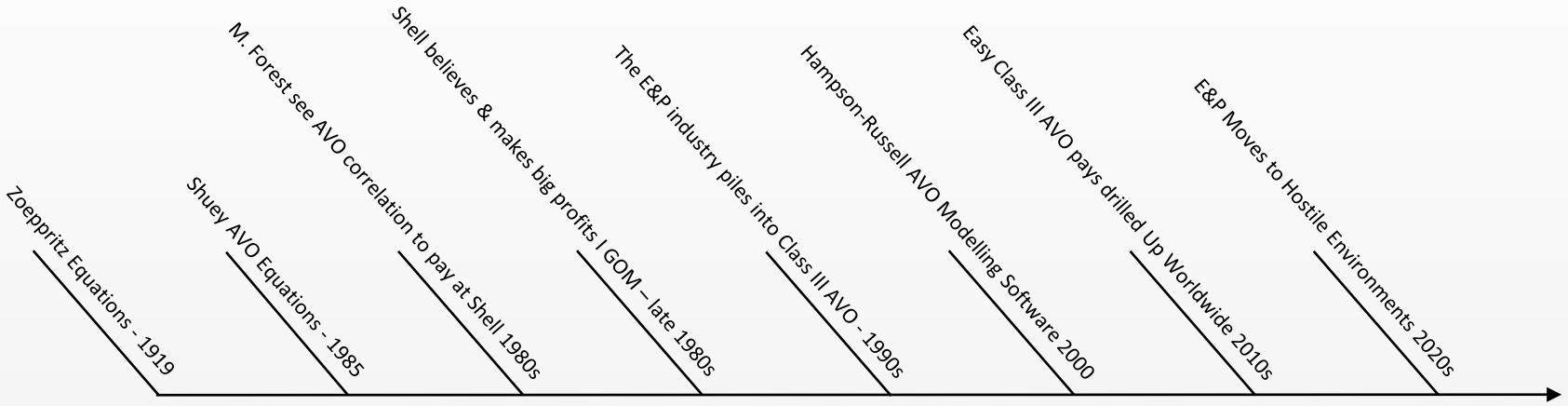



**ADF® has high plan-view resolution**

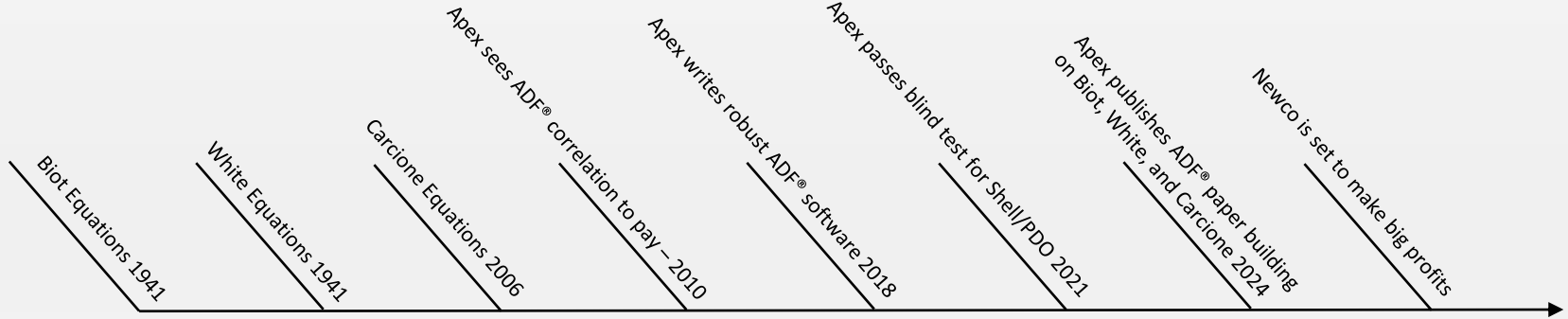
# Some ADF® Projects

APEX






**AVO Timeline**



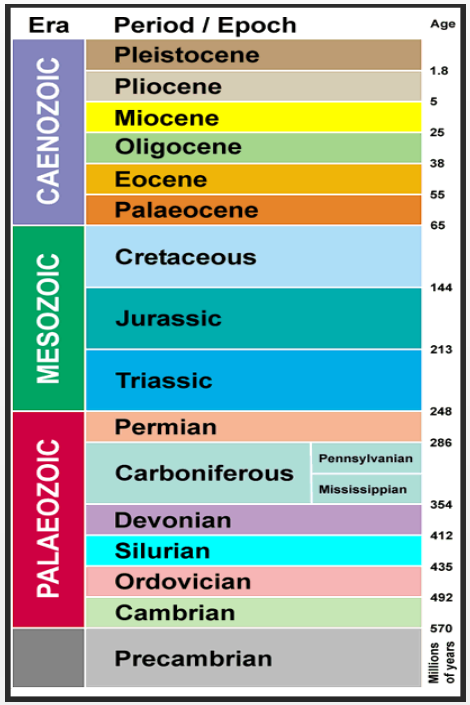

**ADF® Timeline**

# ADF® & AVO Sandstone General Applicability

AVO & Amplitude are **generally effective**

AVO & Amplitude are **sometimes effective**

AVO & Amplitude are generally **not effective**

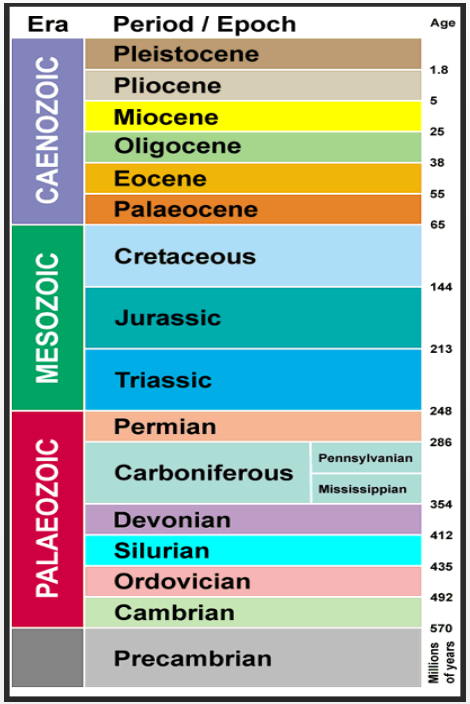



ADF® tends to be **ineffective**

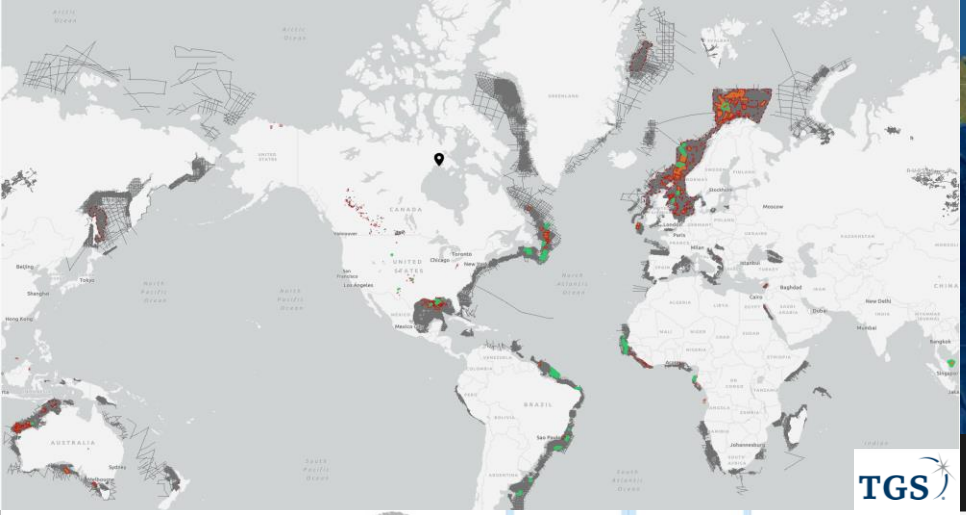
ADF® **materially** de-risk these targets

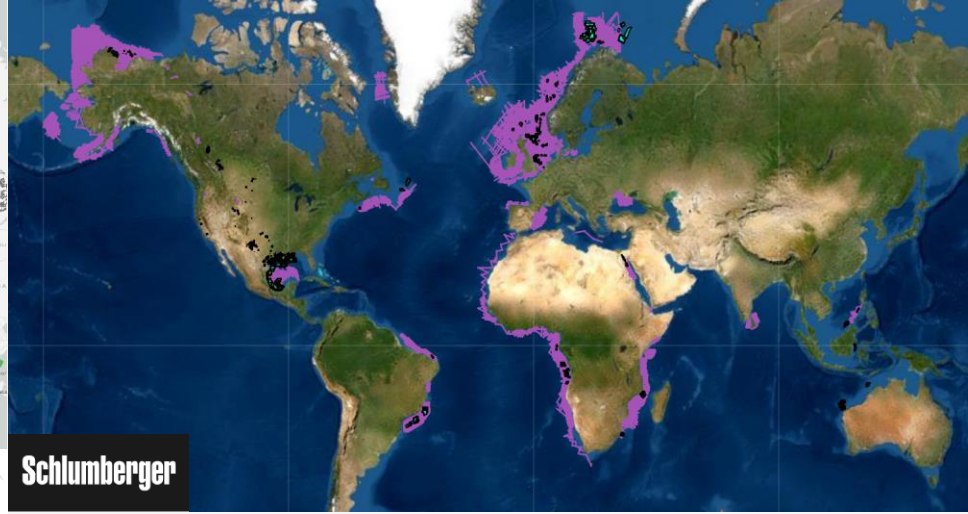
# ADF® & AVO Carbonate Applicability

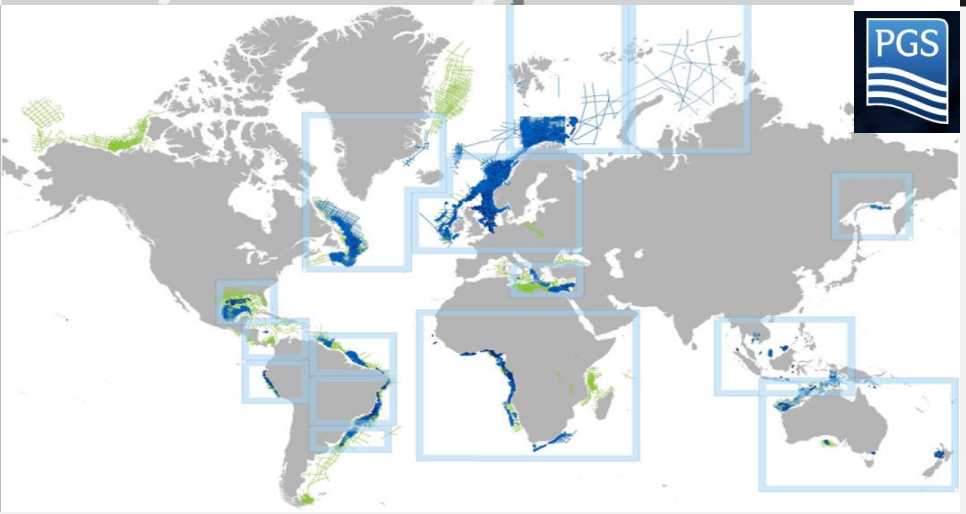
AVO & Amplitude are generally **not effective**




ADF® **materially** de-risk these targets

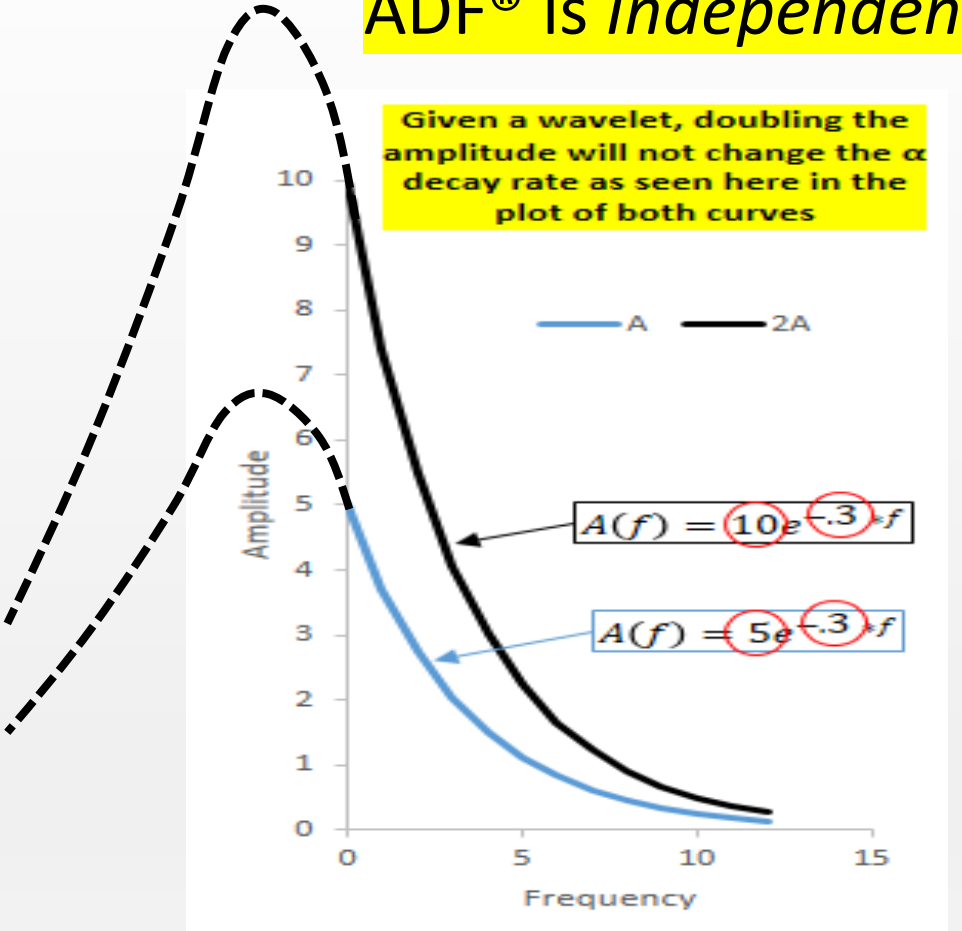



2,000,000 km² of multiclient 3D is available to be reworked

# ADF® is *Independent* from Amplitude




| $A(f) = A_0 e^{-\alpha * f}$ | **α =** | **0.3** |
|---|---|---|
| f | A | 2A |
| 0 | 5 | 10 |
| 1 | 3.7 | 7.4 |
| 2 | 2.7 | 5.5 |
| 3 | 2.0 | 4.1 |
| 4 | 1.5 | 3.0 |
| 5 | 1.1 | 2.2 |
| 6 | 0.8 | 1.7 |
| 7 | 0.6 | 1.2 |
| 8 | 0.5 | 0.9 |
| 9 | 0.3 | 0.7 |
| 10 | 0.2 | 0.5 |
| 11 | 0.2 | 0.4 |
| 12 | 0.1 | 0.3 |

# ADF® Benefits

- Sometimes, directly indicates hydrocarbon charge
- Identifies permeability barriers setting up traps
- Images commercial quality reservoir
- Images a prospective reservoir's aerial extent thereby indicating reserve size
- Spot wells in high borehole deliverability (often critical for commerciality)
- Images depletion effects in existing fields

End