AV Learning from 40 Years Experience: Risking Seismic Amplitude Anomaly Prospects*

Mike Forrest[1]

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[1]Shell Oil (retired) and Maxus Energy (retired), currently Associated Consultant, Rose & Associates , Duncanville, TX (forrestm33@sbcglobal.net)

Final Comments

- Gas or oil replacing water in a reservoir will always cause a change in seismic reflection coefficient and AVO.
- The change can range from “dramatic” to “subtle” to “unrecognizable.”
- Factors:
    - Rock physics
    - Seismic signal-to-noise ratio
    - Geology vs. seismic resolution.
- Review the Seismic and Rock Physics.
- Can DHI’s be a factor in your prospect risk analysis?
- Positive impact – use systematic/consistent work process.
- Negative impact – DHI’s expected but none observed.

Learning from 40 Years Experience
Risking Seismic Amplitude Anomaly Prospects

AAPG Convention, April 2010

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Shell Oil (retired) and Maxus Energy (retired)
Associated Consultant, Rose & Associates

Seismic Amplitude Anomaly Terms

Direct Hydrocarbon Indicator (DHI), Hydrocarbon indicator (HCI): measurement which indicates the possible presence of a hydrocarbon accumulation

Bright spot: local increase in amplitude on a seismic section

Flat Spot: possible hyrocarbon fluid contact

Amplitude variation with offset/angle (AVO, AVA): prestack data, seismic gathers, offset/angle stacks, cross-plots (actually "change in AVO")

Phase (Polarity) Change: seismic peak on stack data changes to a trough (or trough to a peak)

Dim Spot: local decrease in reflection amplitude

40 Years Timeline

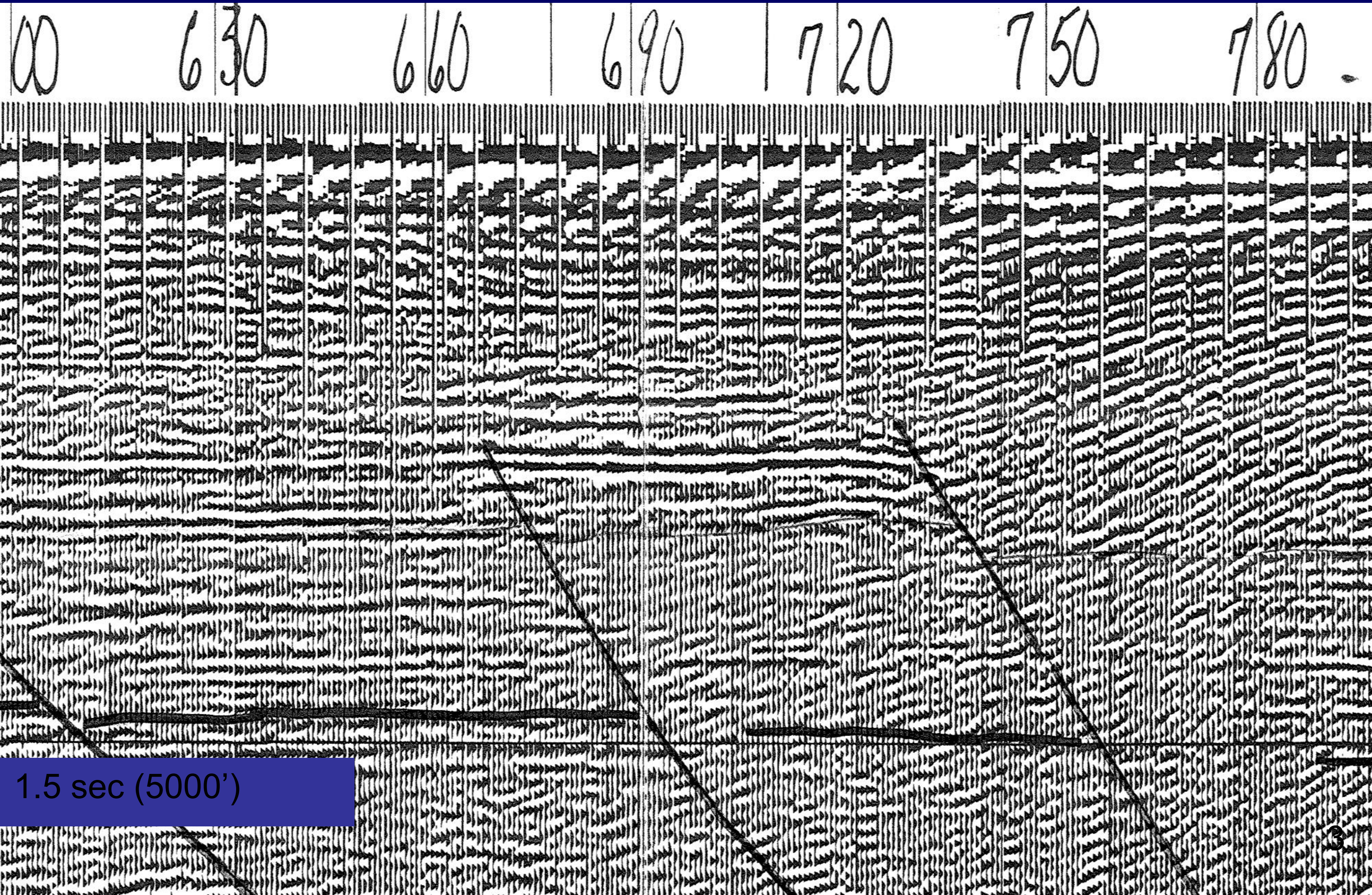
1967 to 1970 – Bright Spot recognition and studies

1970's – GOM Shelf Discoveries

Mid/late 80's – deep water exploration

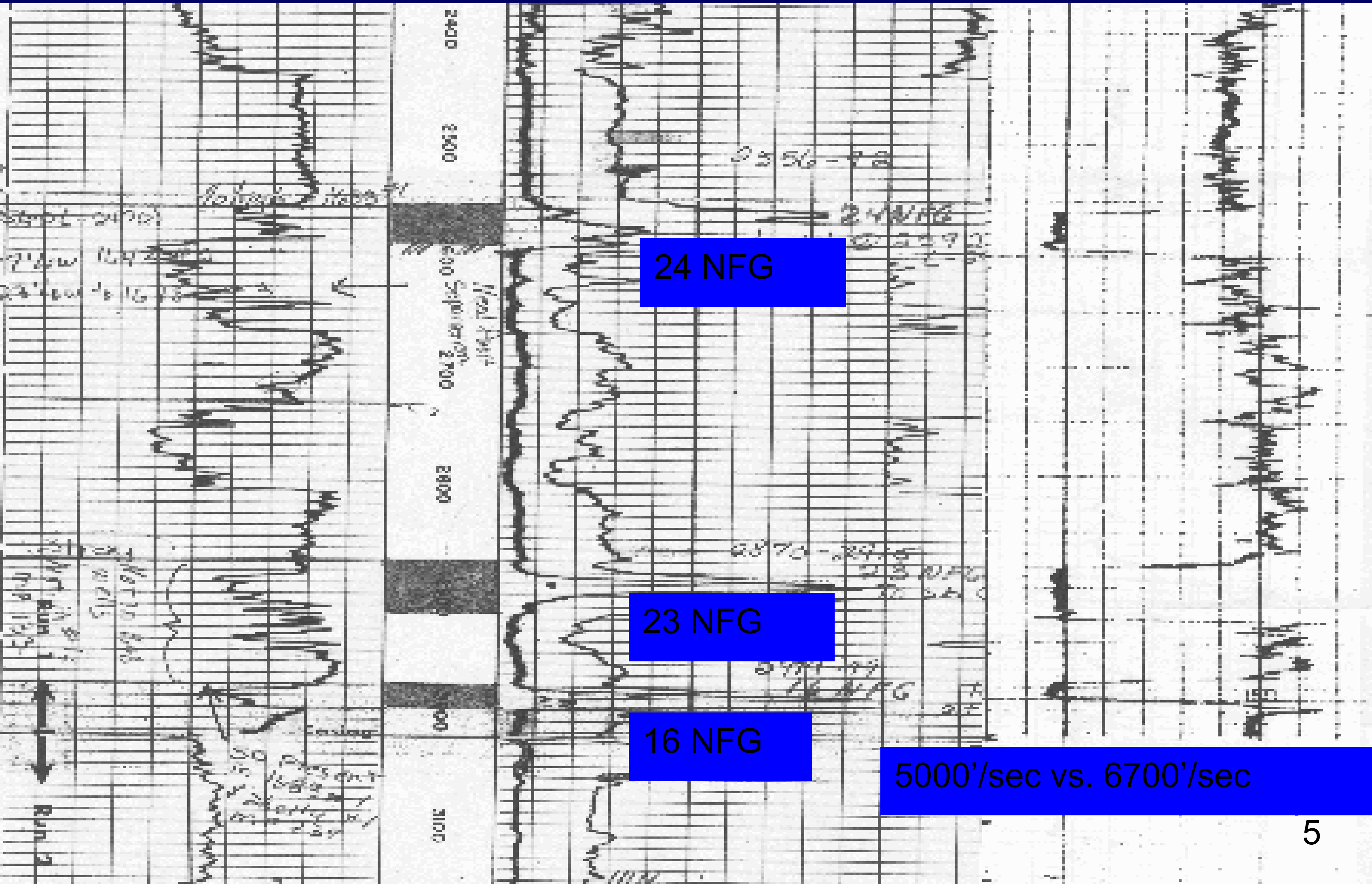
Last 10 years – "lessons learned" in a DHI Consortium

1967: Main Pass 122 - 133 Area



1968, Main Pass 122 -133 Area

## Electric Log 		Sonic Log



“Bright Spot” recognition and studies

Started with an observation and a map, Main Pass Area, GOM

More observations on undrilled Pleistocene GOM prospects

Reviewed several Pliocene-Miocene fields
- seismic and subsurface maps
- logs – petrophysics
- oil and gas areas and pay thicknesses
- relate to seismic data

Lessons: know the data, observations, make maps
- measurements/calibration are essential

1969

"Bright Spot" term coined in Shell

Management Review: Operations/Research team formed

"Peak and Valley" days.

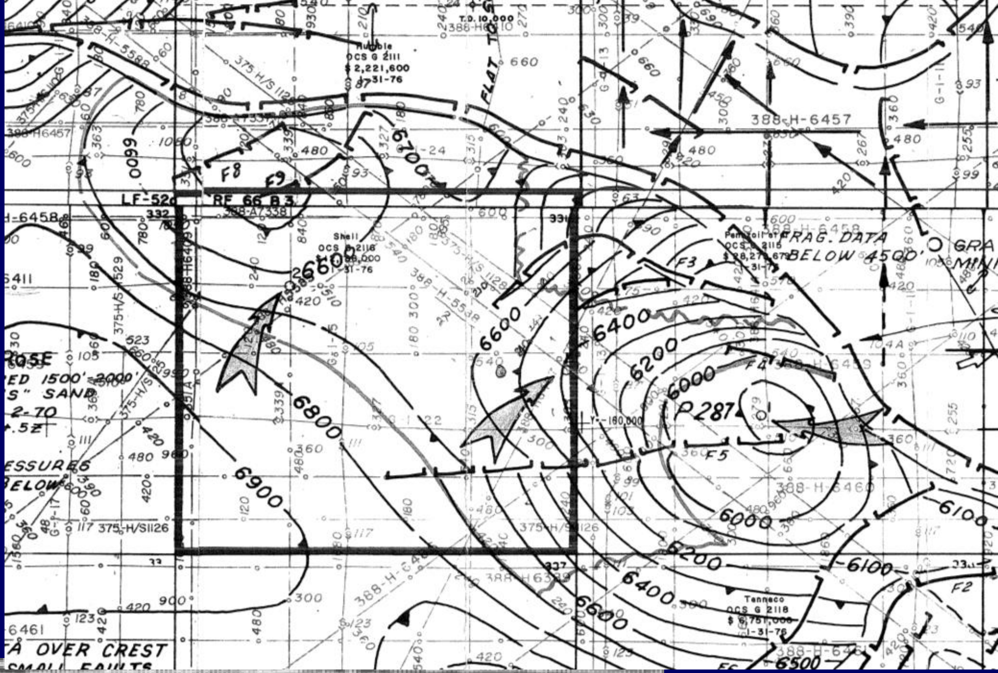
"Digital Revolution" was a major factor – preserve relative amplitude of seismic data

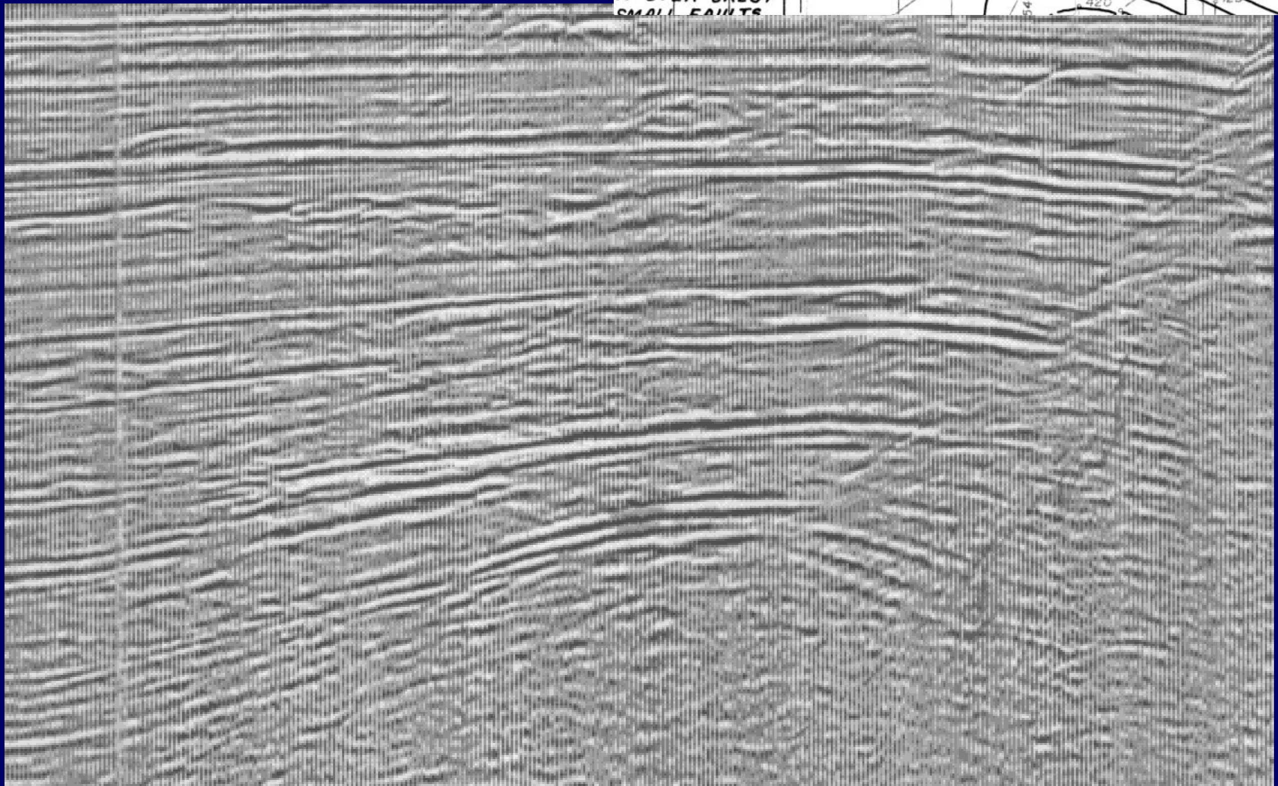
1970

One of first Bright Spot Prospects in Gulf of Mexico (Dec. 1970 Fed. Lease Sale)

EI 330 Field – 750 MMBOE

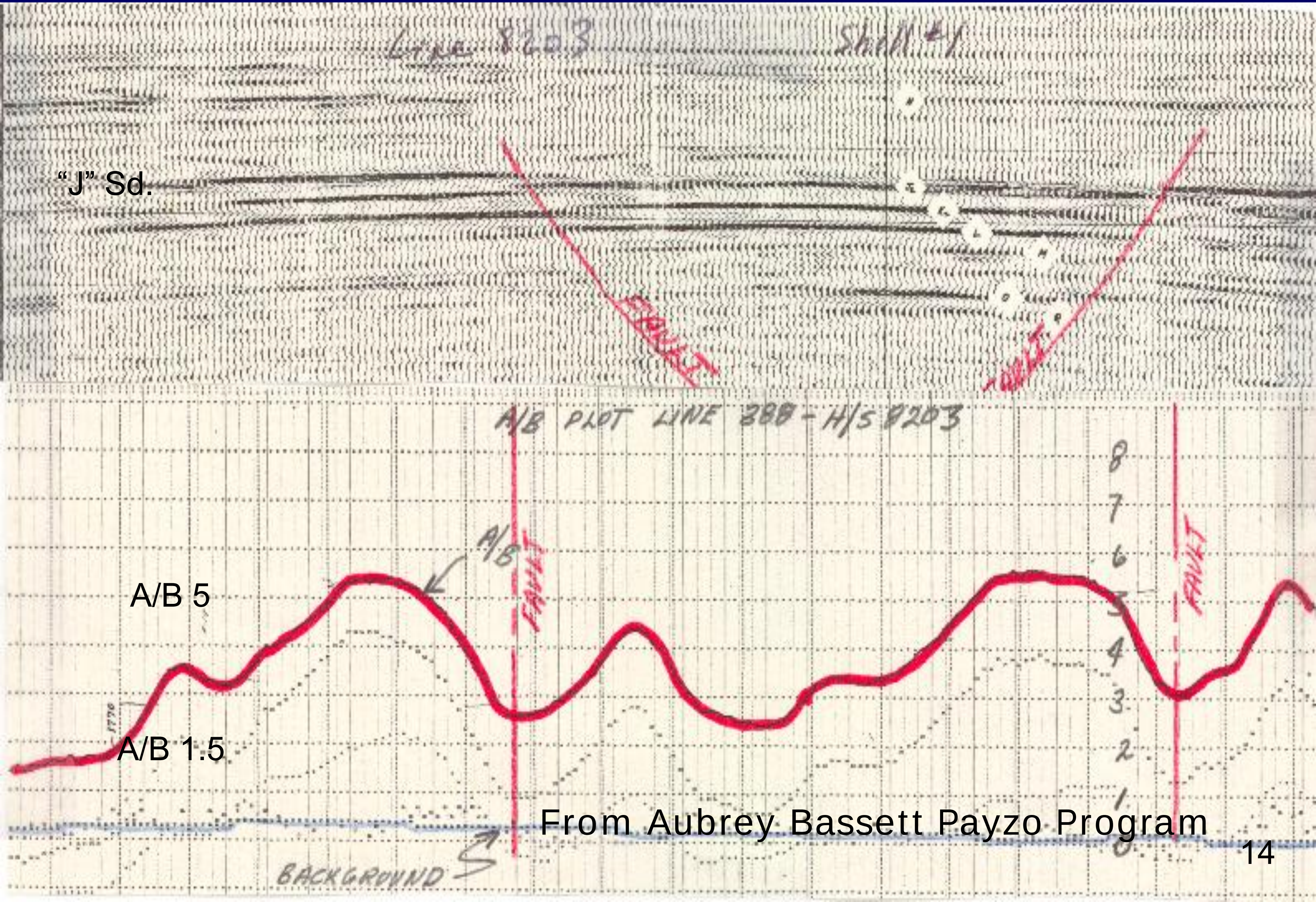
All <u>Bright Spots</u> are oil/gas pays



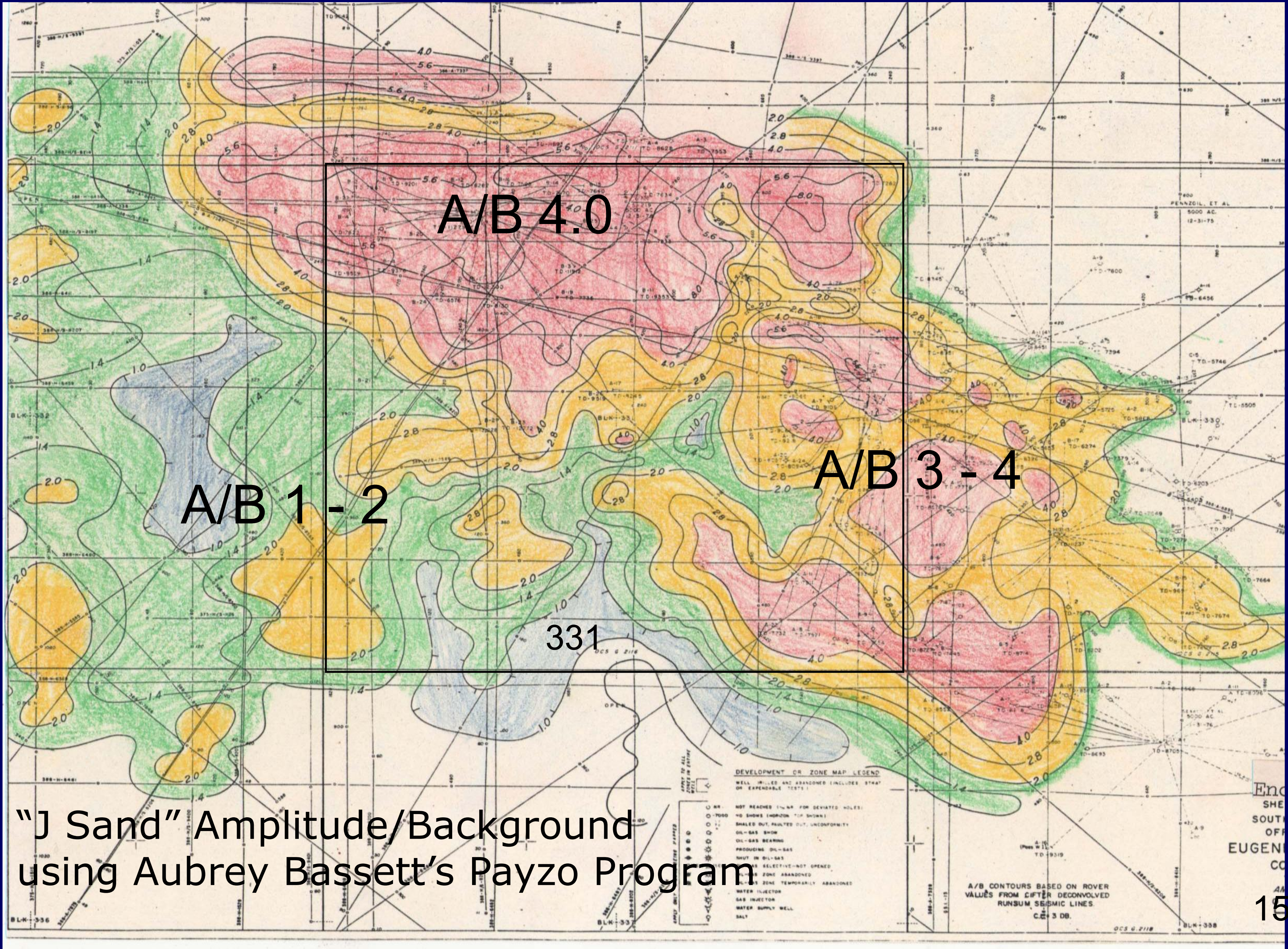


7000’

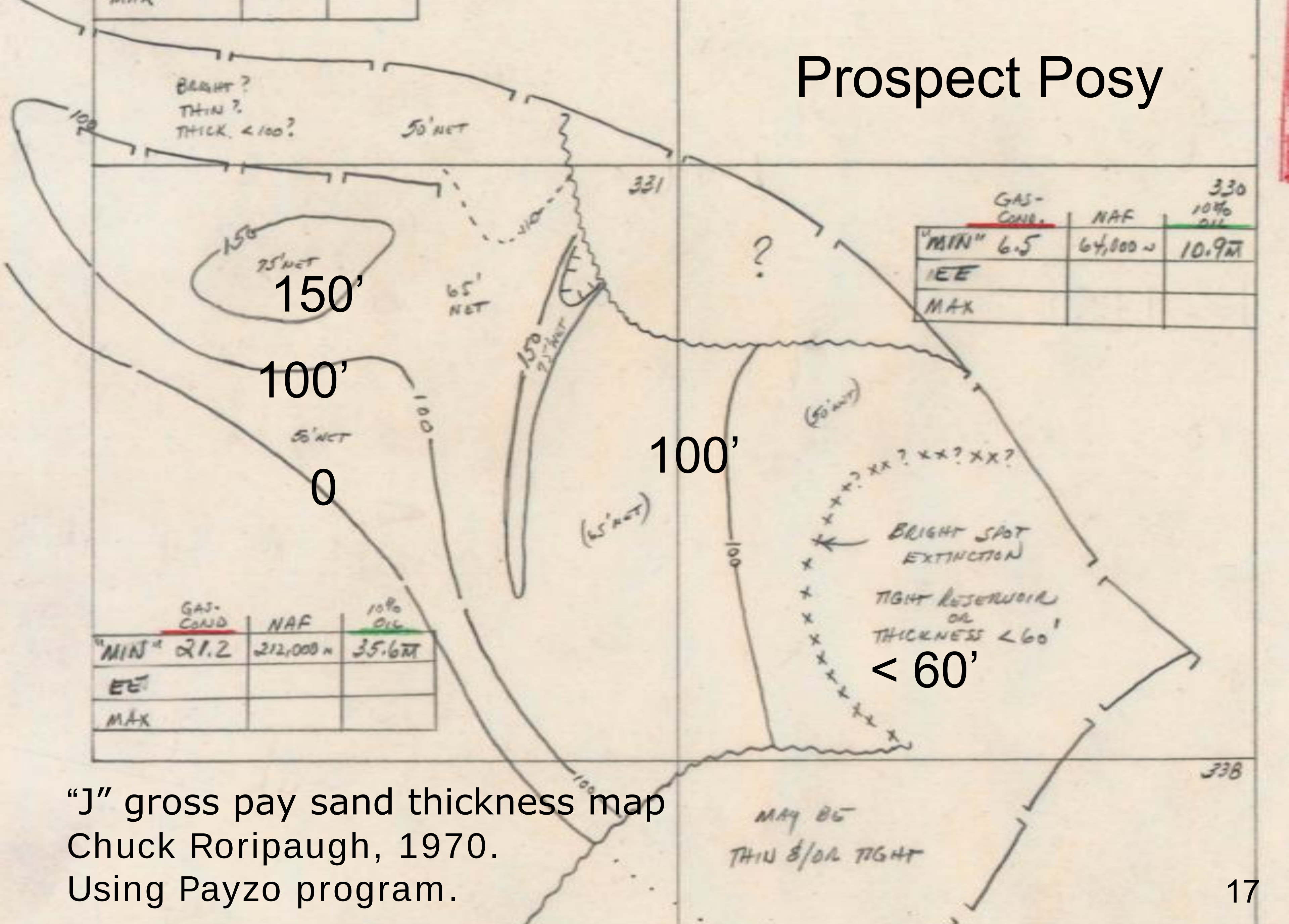
Prospect Posy (EI 330 Field)– Amplitude / Background



Prospect Posy – A/B map at "J" sand level



Prospect Posy



"J" gross pay sand thickness map
Chuck Roripaugh, 1970.
Using Payzo program.

Status in mid 1971

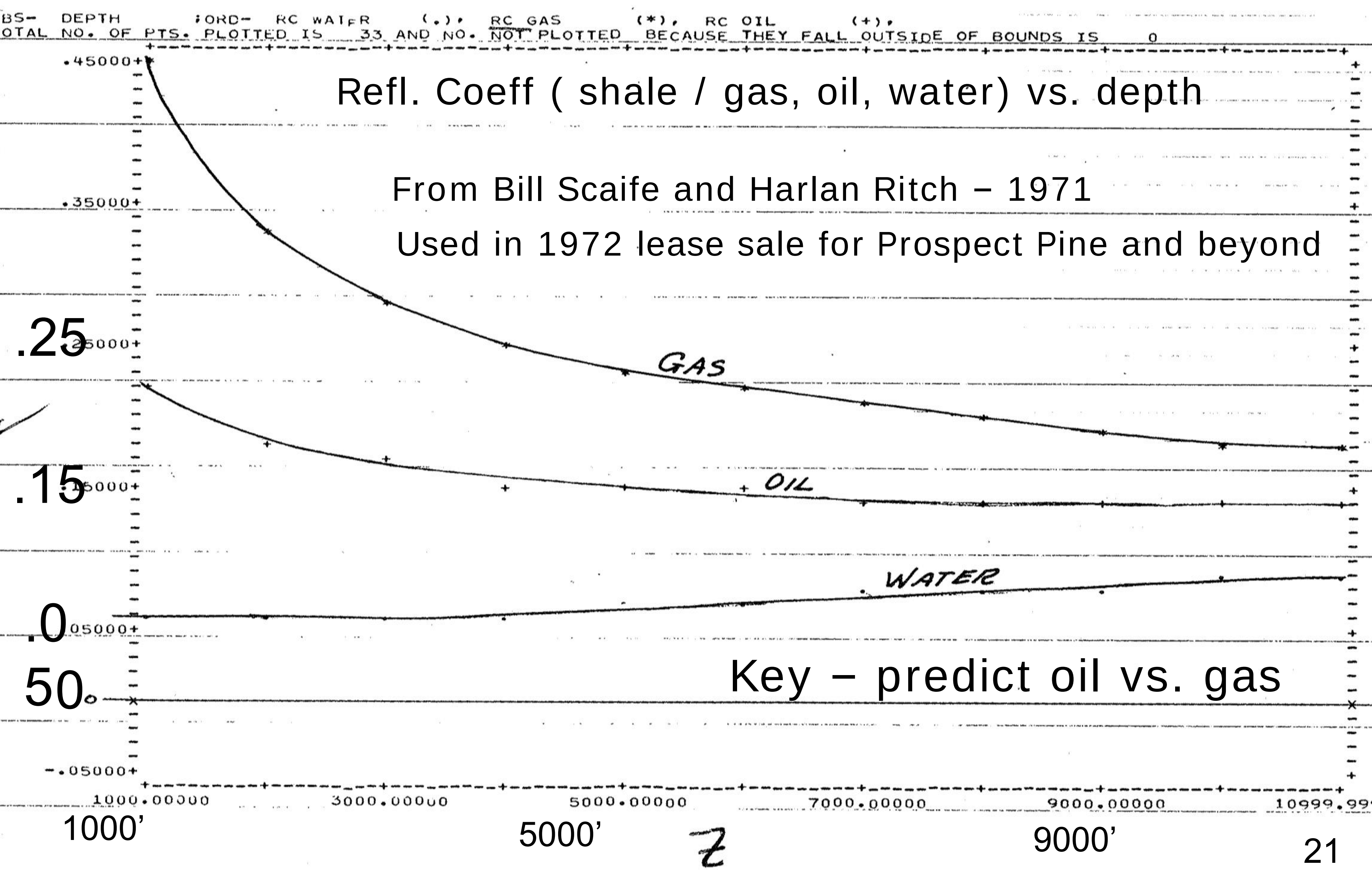
Shell application of Bright Spot technology

- conformance to closure
- amplitude vs. background (A/B)
- thickness measurements
- integrate with geology studies

to estimate resource estimates & probability of success

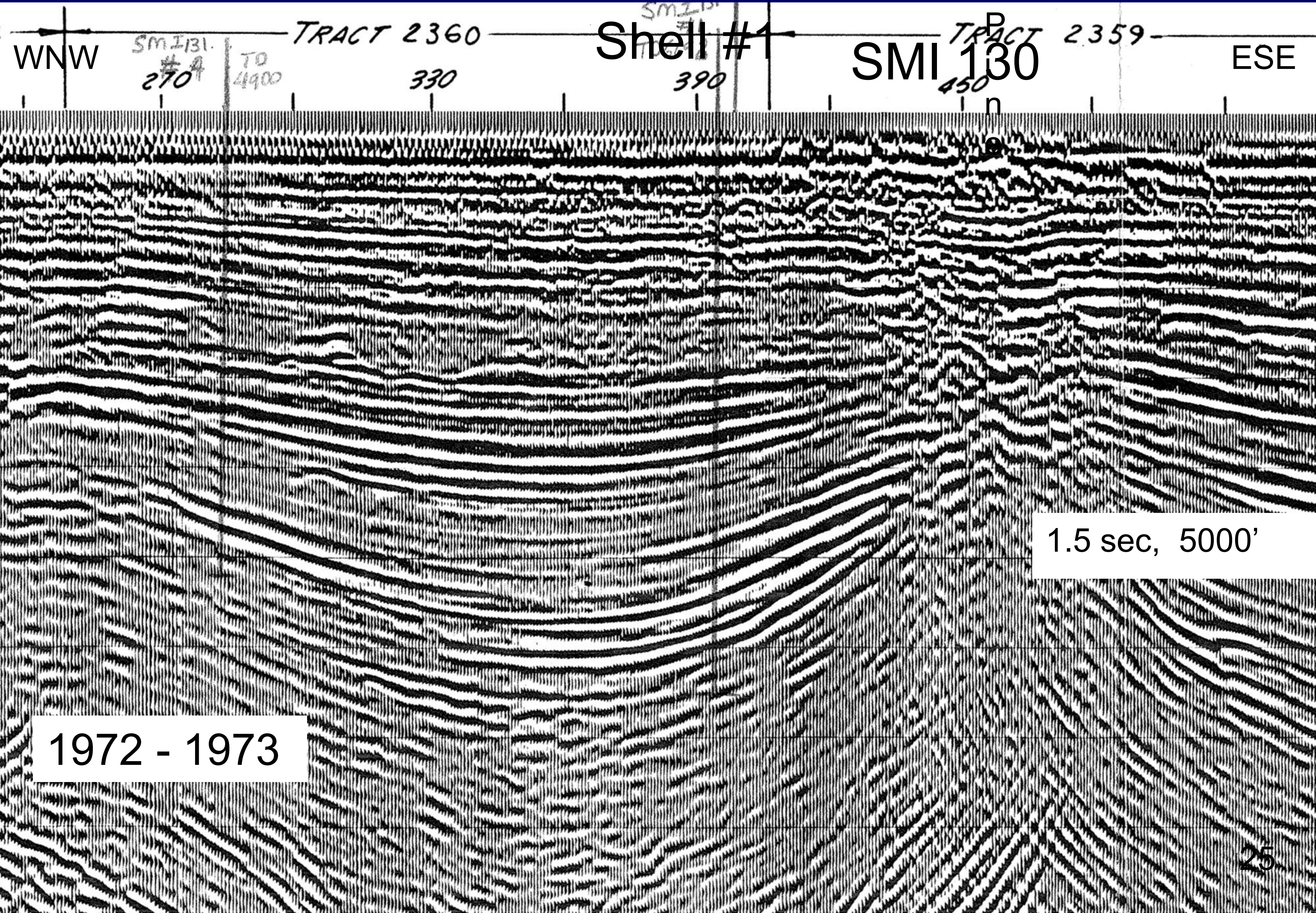
Bright Spot technology was a major part of the bid calculation for 1970 Gulf of Mexico lease sale
--- in my view, "a first"

1971: Plio – Pleistocene "Trend Curves": Calibration"



Prospect Pine (SMI 130 Field)

West Pine



Prospect Pine/West Pine Summary

Related amplitudes to petrophysical “Trend Curves”.

Original estimate of 100 MMBO - high probability “oil calls”.
Ultimate today: 225 MMBOE.

West Pine - first recognition of low saturation gas problem (LSG)
Sand with 10% gas saturation has essentially same reflectivity as sand with 80% gas sat.
Low velocity similar to commercial gas; density effect is minor

1970's – GOM Shelf Discoveries (cont)

Many 20 to 100+ MMBOE Fields
Total Ultimate 1.5 to 2.0 BBO

Cognac field in 1000 ft water

- 1974 lease sale - $50 MM to $100 MM bids per block
- 1975 discovery

Resource estimate essentially 100% Bright Spot supported
Shell bid on 100 MMBO + 500 BCF

Expected ultimate: 180 MMBO and 750 BCF (300 MMBOE)

Lessons: late 1960's and early 70's

Good ideas come from seismic observations, follow-up with research team

Well ties and trend curves (rock physics) – calibration is essential

1973 – first recognition and documentation of low saturation gas pitfall. Still a problem today

New idea requires persistence
"BEWARE OF THE SKEPTICS".

In hindsight, the "Bright Spot" concept is very simple (as often the case in hindsight)

Mid/mid 1980’s – GOM deep water exploration

Mid – late 80’s Gulf of Mexico – 2000+/- ft water
Area Wide Sales a major factor in success
Shell discoveries – Bullwinkle – 150 MMBOE
Popeye – 225 BCF
Tahoe – 85 MMBOE

1985 to 1987 – expansion out to 6000 ft water (above salt)
Discoveries – Auger - 375 MMBOE
Mensa – 700 BCF
Mars/Ursa – 1.5 B Blls

Keys to success: map sand fairways
understand salt tectonics
careful analysis of Bright Spots

2001 to today

Many “lessons learned” in a DHI Consortium

First step in Interpretation and Risk Analysis Work Process

"Geology Studies"

Regional geology studies – easy to undervalue

Prospect Probability of Success using Geology Chance Factors, independent of the amplitude anomaly

Before

Detail seismic attribute and DHI analysis

“ Seismic and Rock Physics Data Quality”

Understand Seismic Acquisition and Processing Parameters

“Surprising how often this is not done”

Save the seismic gathers – QC check and AVO

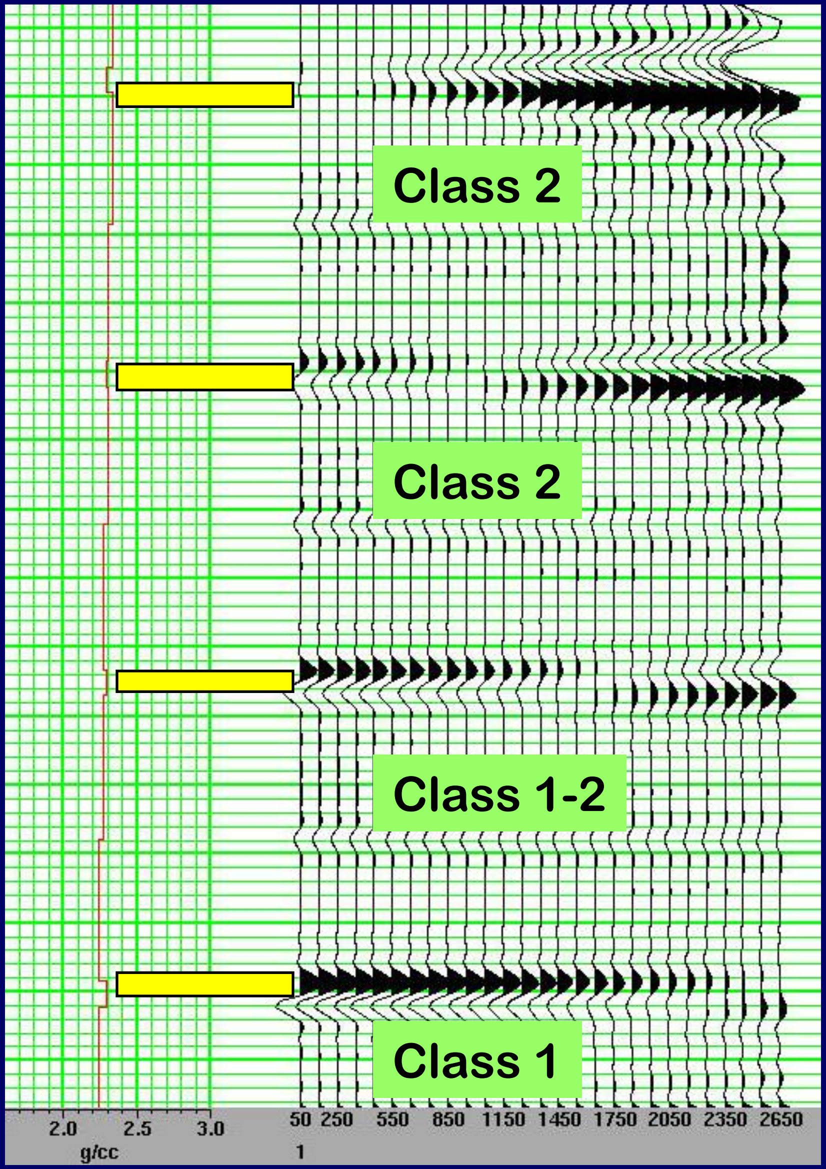
Tie seismic to rock physics data – forward modeling

Seismic and rock physics data quality are key factors in amplitude analysis

Save the Seismic Gathers (model examples)

Emphasis today ---
Class 2 AVO prospects
- moderate consolidated sands
- stratigraphic traps
- onshore areas

Change in AVO “from prospect to location off closure” is critical



AVO Gas Sand Models Seismic Gathers

Galen Treadgold, Weinman Geophysical

Presence of multiple seismic amplitude characteristics is important

Nine categories with several questions per category

1. Local Changes in Amplitude
2. Edge Effects
3. Rock Physics
4. Primary AVO Effects
5. AVO Attribute Cross-plots (Intercept vs. Gradient)
6. Pitfalls
7. Vertical and Lateral Context
8. Seismic Analogs
9. Containment and Preservation

Consider Pitfalls: Reasons for Failure

175-prospect database study

83 Failures (47% of all prospects)

	TOTAL	*% OF ALL PROSPECTS*
Wet Sands	**41**	**23%**
LSG	**19**	**11%**
No Reservoir	**14**	**8%**
Tight Sands	**9**	**5%**

Reasons For Failure (details)

(83 failures of 175 prospects)

Very common
- all areas

- **Wet Sand (no closure or no seal)**
  - high porosity clean sand
  - hard shale, marl, or tuff above sand
  - AVO tuning

Mostly GOM
& Far East

- **Low Saturation Gas (no seal)**
  - 5% to 10% free gas saturation
  - "sprung traps", sometimes related to column height

- **No Reservoir**
  - siltstone, condensed zone, marl
  - top hard pressures.
  - soft shale
  - seismic processing artifact

“DHI Success Factors”

Start with regional and prospect geology

Understand seismic and rock physics data quality

Evaluate multiple seismic amplitude attributes –
Cannot stress enough.

AVO alone does not equal hydrocarbons

Systematic and Consistent Risk Assessment Process.

In the end, It’s really about -
Details, Focus, Data Quality, Geology,
Multiple Anomaly Characteristics, Calibration,
and especially “Thinking”

Discoveries and Future Opportunities

Last 10 years – DHI Discoveries

Angola and Nigeria

Ghana – Jubilee

Lake Albert – Uganda

Future opportunities –

International deep-water basins

GOM deep overpressured prospects?

Onshore areas – older rocks, subtle anomalies

Final

Gas or oil replacing water in a reservoir will always cause a change in seismic reflection coefficient and AVO.

The change can range from "dramatic" to "subtle" to "unrecognizable".

Factors: *rock physics*
seismic signal-to-noise ratio
geology vs. seismic resolution

Review the Seismic and Rock Physics ---
Can DHI's be a factor in your prospect risk analysis?

Positive impact – use systematic/consistent work process

Negative impact – DHI's expected but none observed