Seismic Amplitude and Risk: A Sense Check

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Disclaimer

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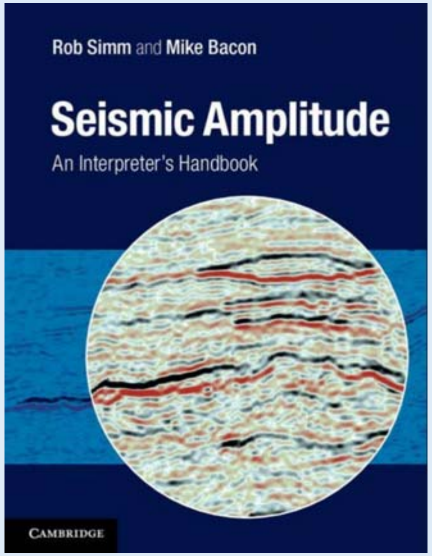
Mike Bacon (1946-2016)

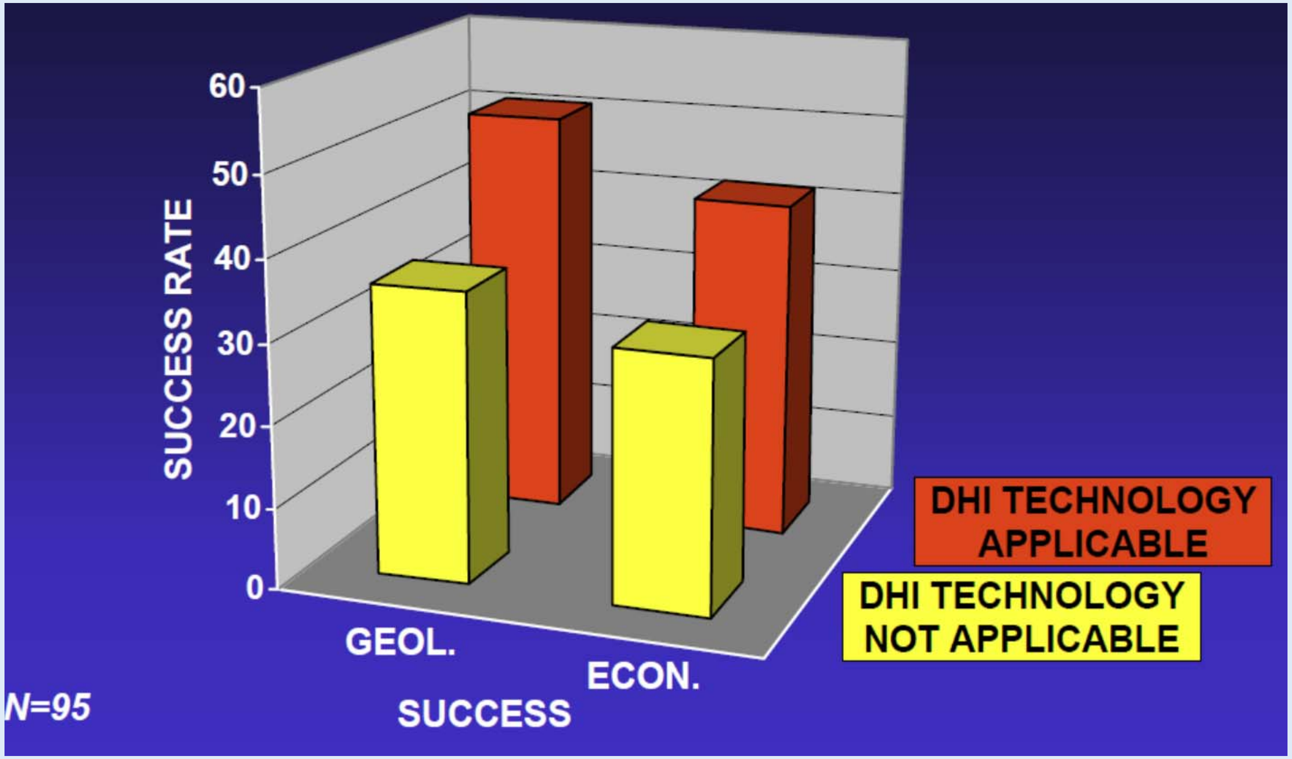


$$P(hc \mid dhi) = \frac{P(dhi \mid hc)P(hc)}{P(dhi \mid hc) + P(dhi \mid nohc)P(nohc)}$$

An intuitive tool for geologists?

Chasing Amplitudes Makes Sense
(where applicable)

Wildcat Success Rates – Exxon

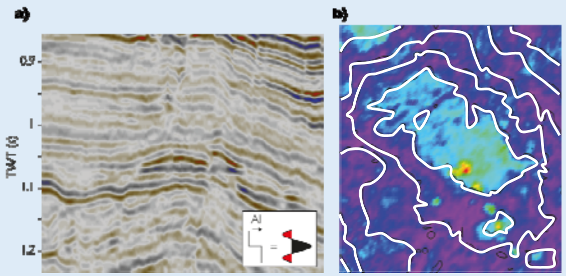


Rudolph (2001), Fahmy and Reilly (2006)

First order 'DHI type' seismic effects

Amplitude anomaly consistency with structure

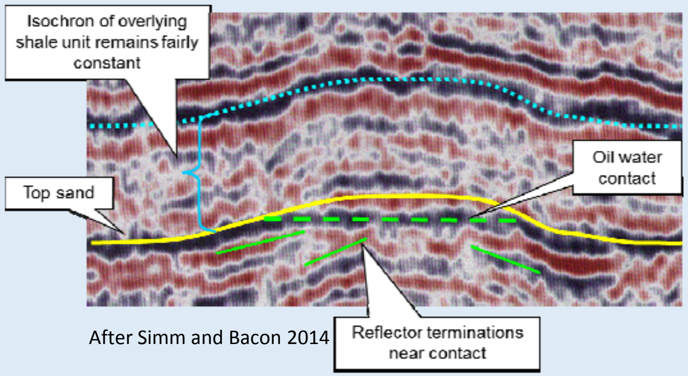
Contact effects (flat spots)



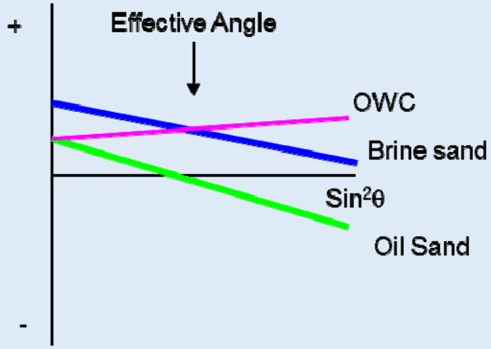
After Simm and Bacon 2014

Reflector terminations (near contact)

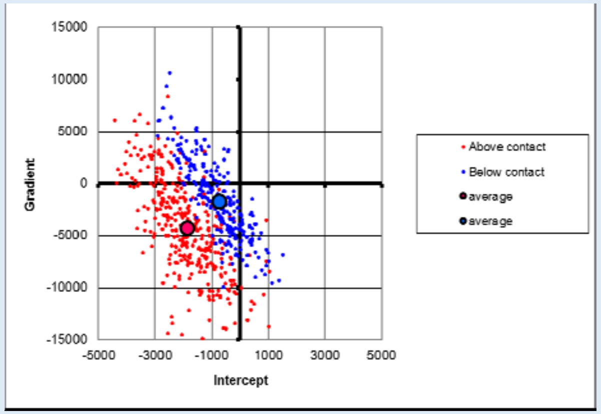
Correlative amplitude change at top reservoir (consistent with rock physics model)



After Simm and Bacon 2014

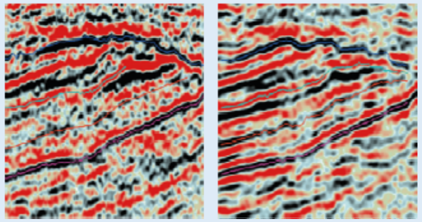


AVO Fluid Vector



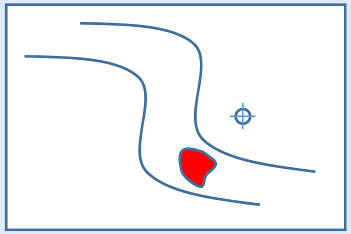
Quality Factors for 'DHI type' effects

Seismic data quality

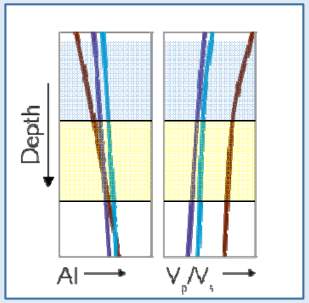


After Thompson et al 2007

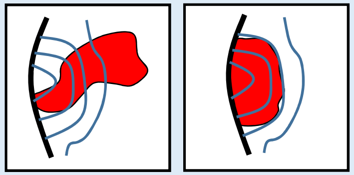
Proximity to relevant calibration



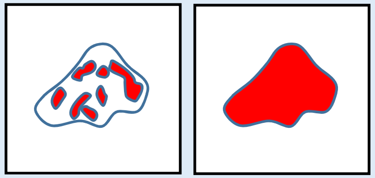
Stratigraphic (and depth) consistency of prospect with analogues/wells for modelling



Degree of structural conformance



Spatial consistency of amplitude anomaly



Pitfalls: Lithology and Data Effects

- *Wet sand*
  - *High porosity*
  - *Tuning effects*
- *Low saturation gas*
- *Tight reservoir*
- *No reservoir*
  - *Shale (low density)*
  - *Volcanic ash (micro porosity)*
  - *Coal*
  - *Hydrocarbon charged marl*
  - *Overpressure*
  - *Mud volcano*
  - *Tar mat*
  - *Thickness changes (tuning)*

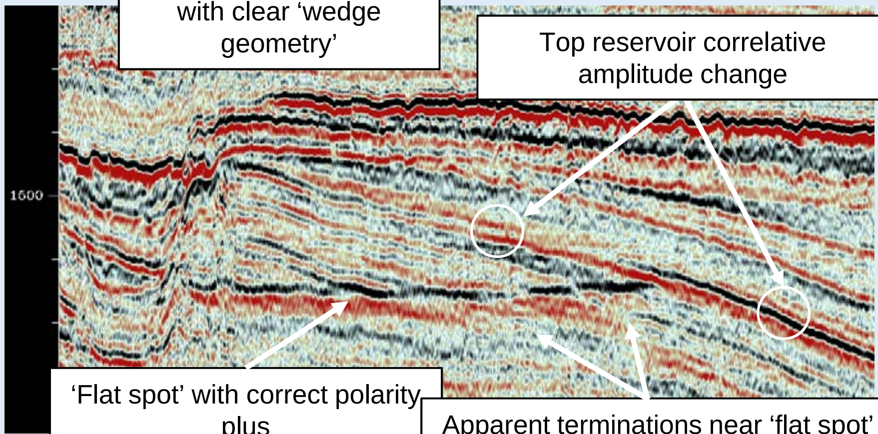
- ***Seismic acquisition and processing artefacts***
- ***Multiples***

- *Diagenetic boundaries*
  - *Opal CT transition*
  - *Cementation effect (e.g. Porosity change across Palaeo contact)*
- *Low impedance siltstone or shale*
- *Anisotropic effect?*
- *Polarity issues – salt, volcanics, carbonates*

Two ends of the spectrum

Multiple Consistent DHI effects

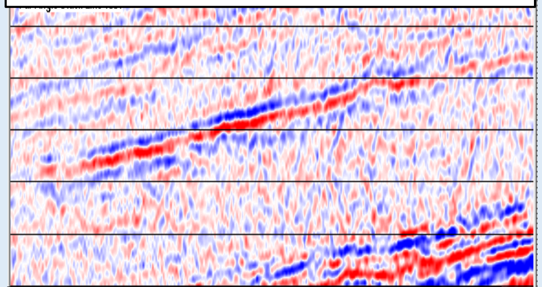
A



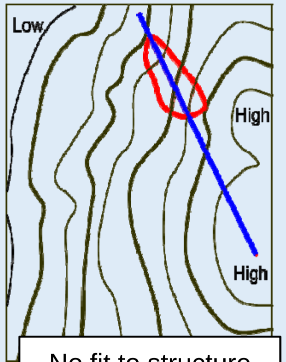
Migrated full stack

B

Amplitude Anomaly – single effect



Class III Anomaly – Far offset stack



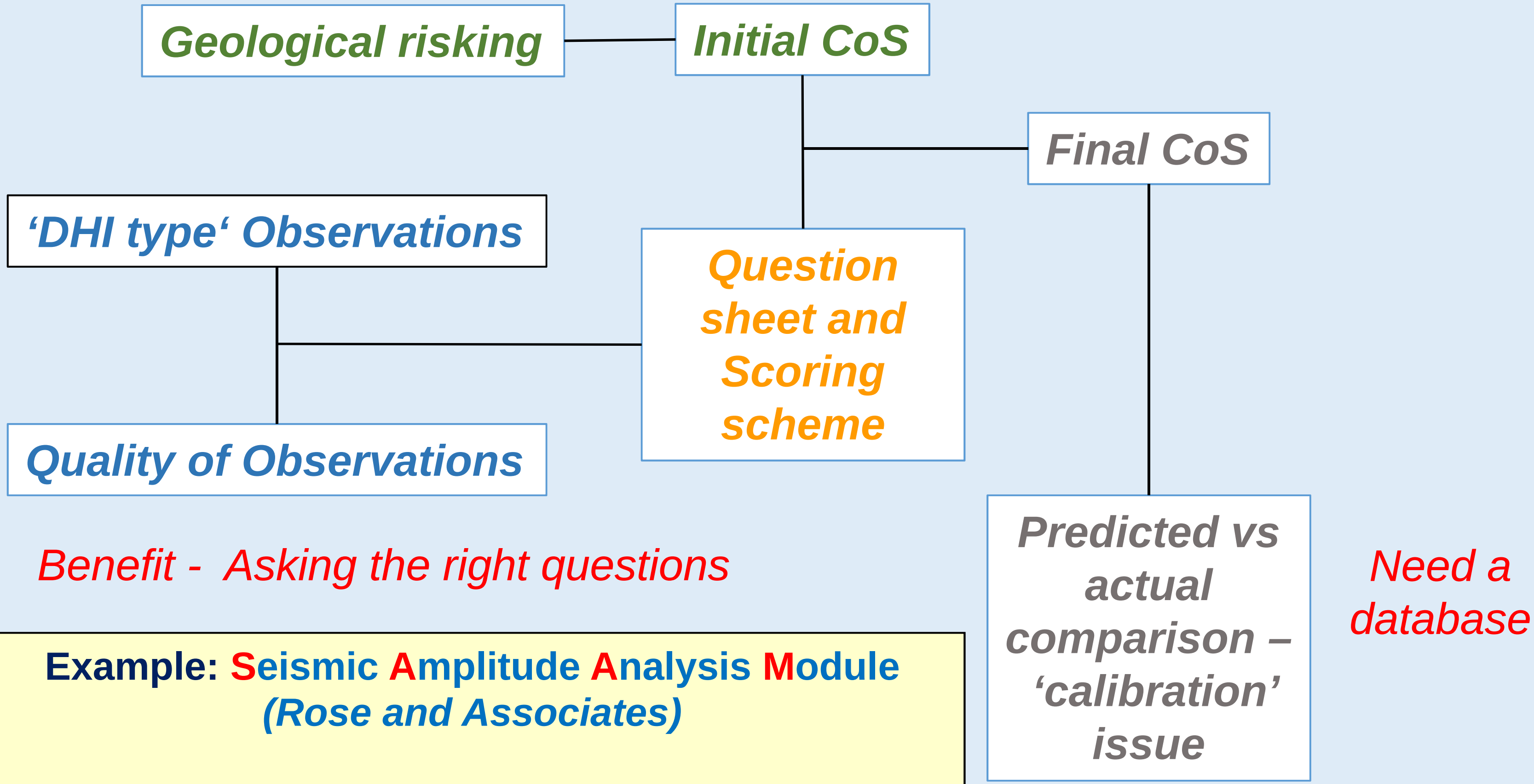
No fit to structure

After Simm and Bacon 2014

Using Amplitude Information in Risk

- Assigning significance to seismic observations is fundamentally subjective …
- Two possible approaches ..
  - Incorporate directly into traditional risking
  - Apply an amplitude based risk modifier to the geological chance of success
- Update approach is not perfect
  - There are issues over how geological risk is separated from the modification
- but …
  - Enables the tracking of how amplitudes are used – provides a learning tool

Amplitude Update Approach



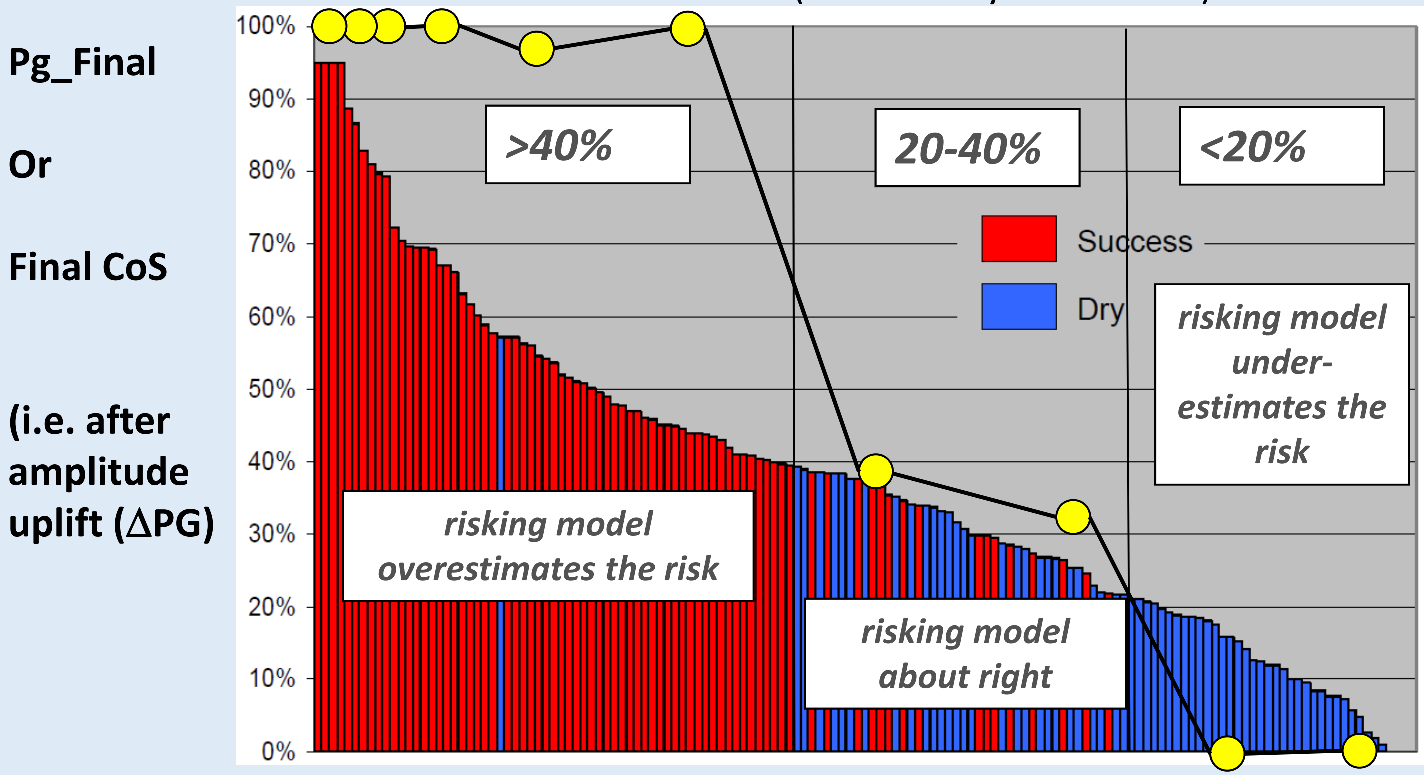
Example: Seismic Amplitude Analysis Module
(Rose and Associates)

Large number of questions dependent on AVO scenario
To determine DHI Index (ΔPg%)

helpful publications and benchmark statistics

SAAM database (145 wells)
Roden et al (2010)

Actual Success (flowable hydrocarbons)



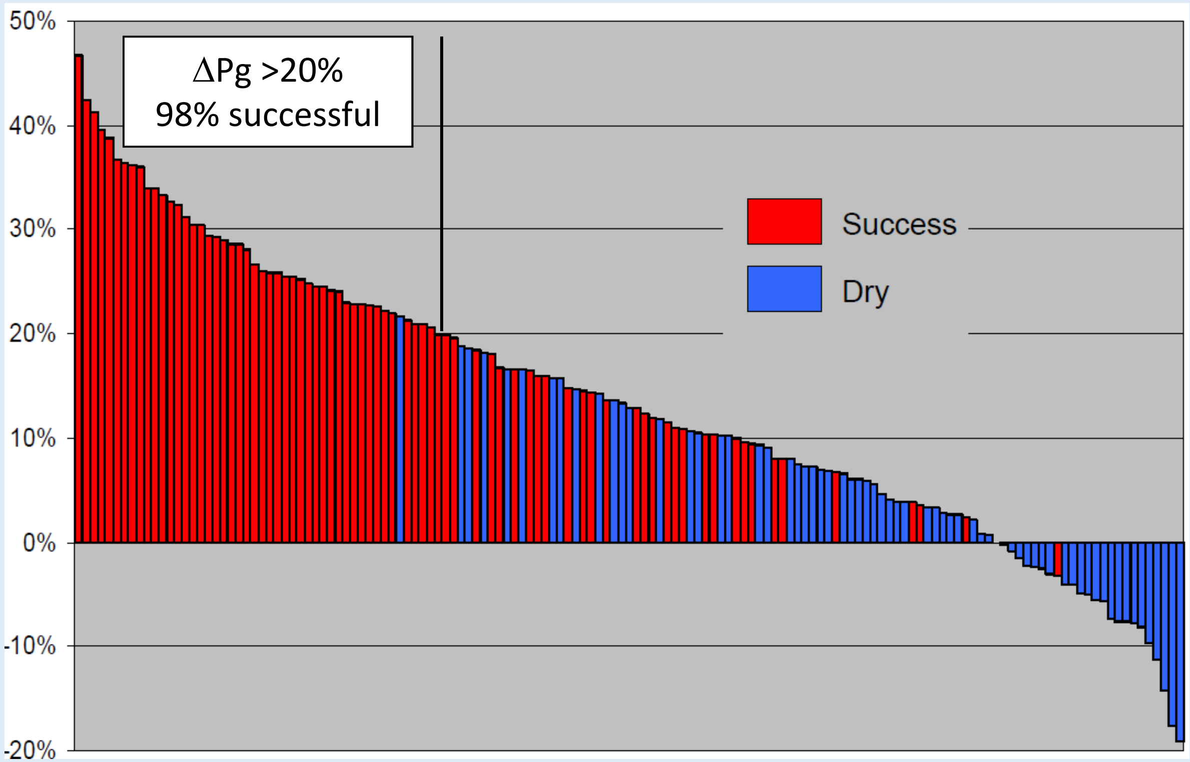
Despite the myriad of questions … we don't appear to be very good at amplitude risking … precision is not accuracy … Final Pg needs 'calibrating'

There are essentially 3 types of 'Amplitude Prospects'

Knowing the type of risking scenario is probably more important than the Precise Final Pg

SAAM database (145 wells)
Roden et al (2010)

DHI Index
ΔPG %



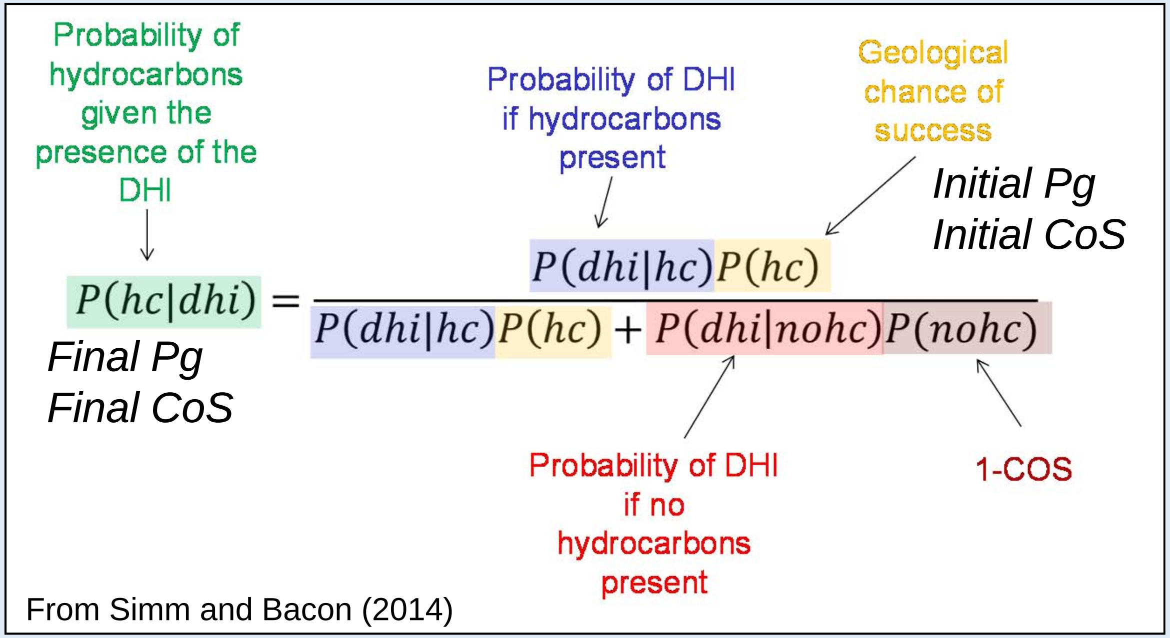
Observations from SAAM Publications (Roden et al 2010, 2012, 2014)

- High success rates with
  - multiple positive DHI characteristics
    - Conformance to structure
    - Correlative amplitude changes consistent with a rock physics model
    - High degree of consistency of anomaly within prospect
    - Contact effects
  - ΔPg uplift >20%, >40% Final Pg
  - Proximity of well control (<1 mile)
  - (Multiple) well calibration with identical stratigraphy
  - Prospects in which the observations can be modelled

SAAM – informative process – but a 'black box'?

What if you are not a consortium member?
Is there a sense check you can make?

Simple Bayesian Risking Formulation



$$P(hc|dhi) = \frac{P(dhi|hc)P(hc)}{P(dhi|hc)P(hc) + P(dhi|nohc)P(nohc)}$$

From Simm and Bacon (2014)

Simple Bayesian Risking Formulation

$$P(hc \mid dhi) = \frac{P(dhi \mid hc)P(hc)}{P(dhi \mid hc) + P(dhi \mid nohc)P(nohc)}$$

Mike's examples from the book …

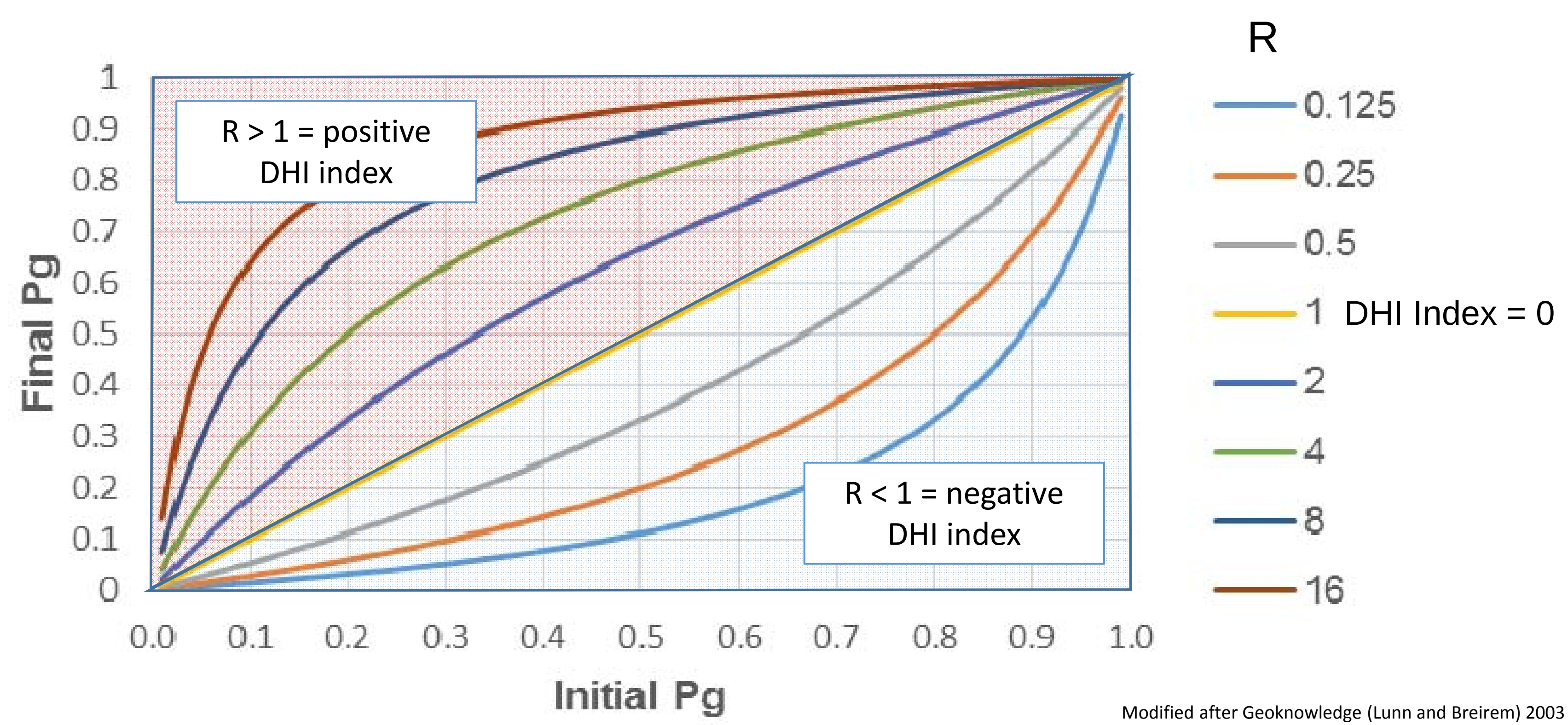
	A	B	C
Initial CoS (P(Hc))	30%	30%	30%
P(dhi|hc)	0.7	0.6	0.6
P(dhi|nohc)	0.2	0.4	0.6
Final CoS (P(hc|dhi)	60%	39%	30%
Uplift/Update/DHI Index	30%	9%	0%

Magnitude of update related to $\frac{P(dhi|hc)}{P(dhi|nohc)} = \mathrm{R}$

$$FinalPg = \frac{InitialPg.R}{InitialPg.R + (1 - InitialPg)}$$

$$R = \frac{1 - InitialPg}{InitialPg.\left(FinalPg^{-1} - 1\right)}$$

Simple Bayesian Model for Pg (initial and final), R and DHI Index



Modified after Geoknowledge (Lunn and Breirem) 2003

Useful way of visualising prospect database

Uplift / DHI Index depends on magnitude of R and also Initial Pg

A Simple Bayesian Risking Formulation

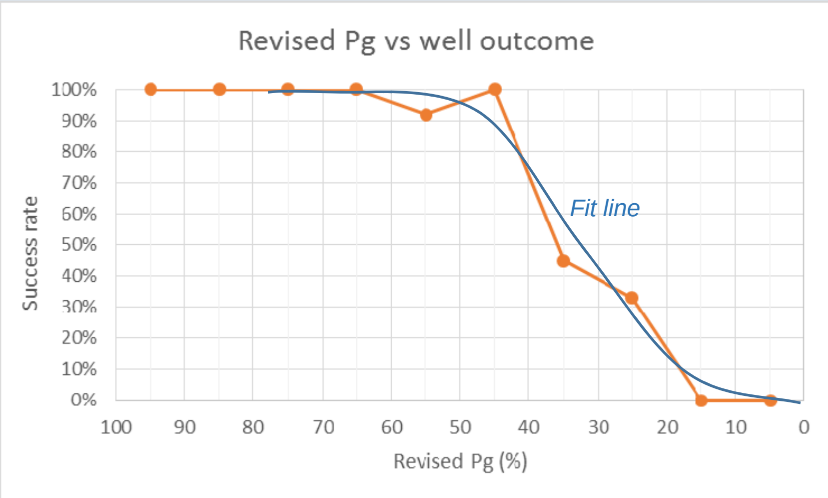
Mike's examples from the book …

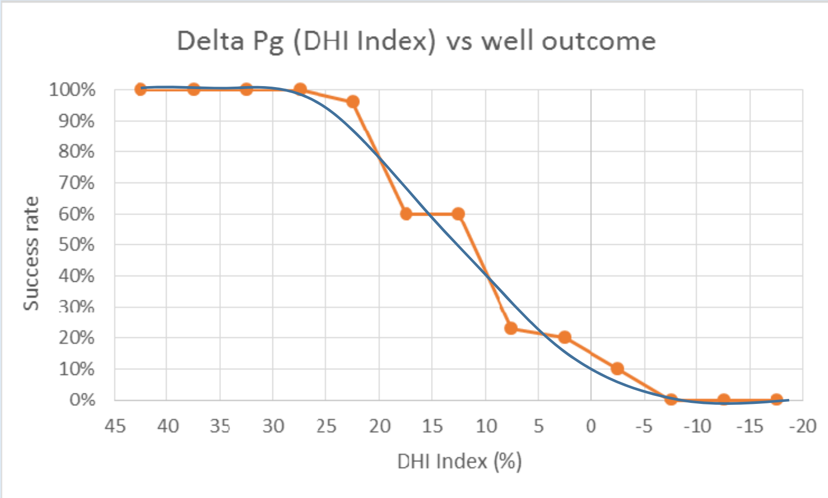
	A	B	C
Initial CoS … P(hc)	30%	30%	30%
P(dhi|hc)	0.7	0.6	0.6
P(dhi|nohc)	0.2	0.4	0.6
Final CoS … P(hc|dhi)	60%	39%	30%
Uplift/Update/DHI Index	30%	9%	0%
R	3.5	1.5	1

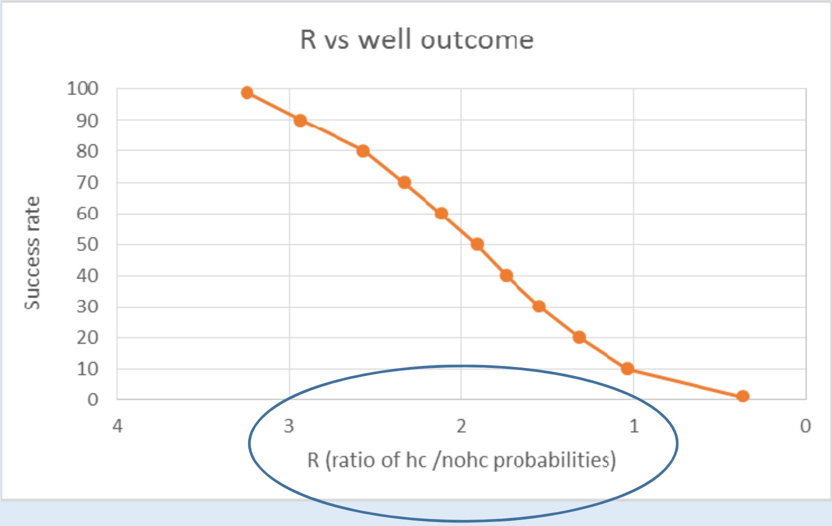
How do these values relate to real prospect scenarios?

Typical values of (uncalibrated) R

SAAM data - Roden et al (2010)



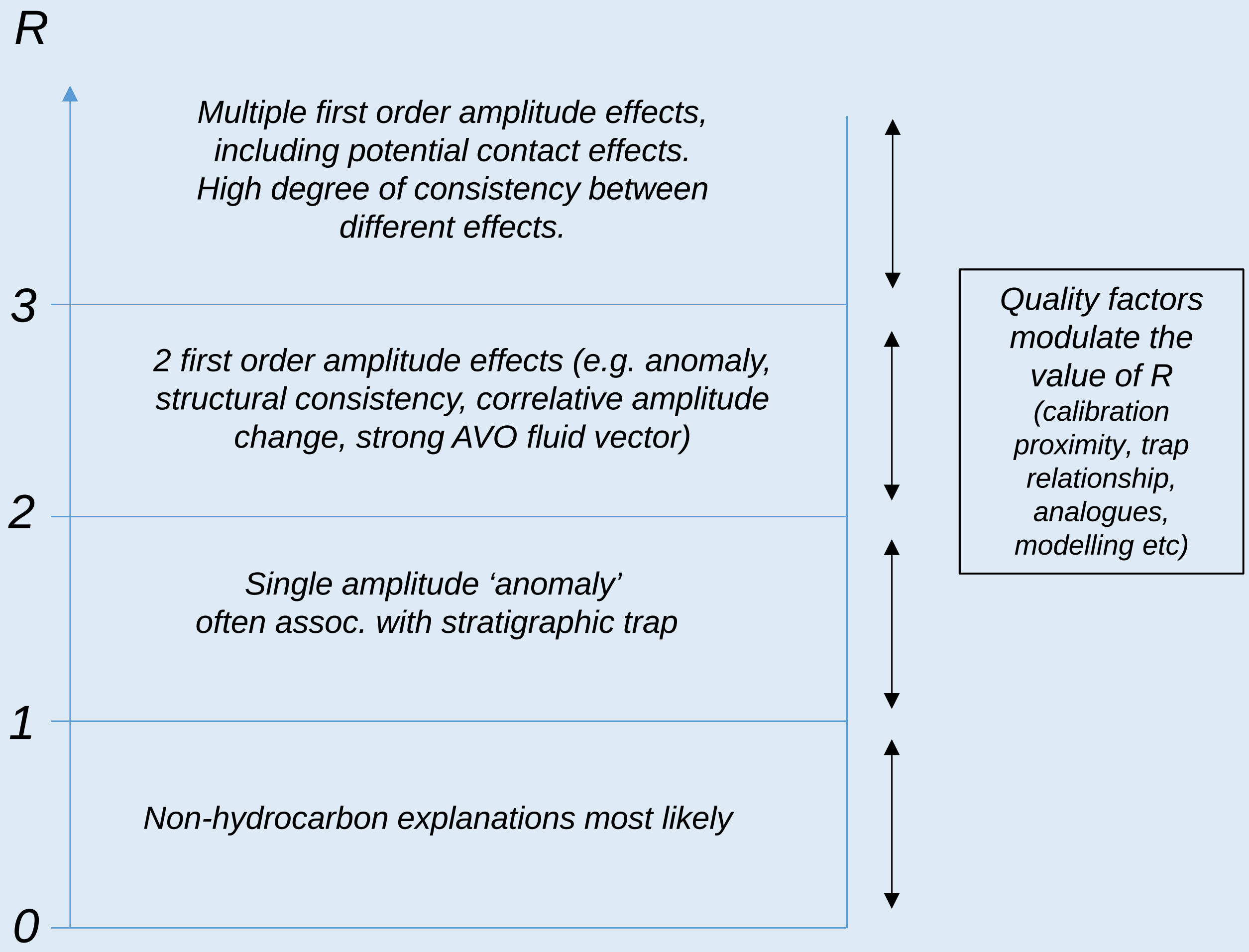




R derived from fit lines of final Pg and DHI index for given success rates

General range of R = 1-3 (10-90% success rate)

A Rule of Thumb Framework for R



Conclusions

- The Simple Bayesian Formulation is a useful tool for getting a sense check on the impact of amplitude information in risk
- The key parameter is R
  - relative probability of hydrocarbon and non hydrocarbon interpretations for 'DHI type' observations
- A simple 'rule of thumb' framework can be invoked that is consistent with published data from Rose Associates Consortium
  - R relates directly to number of first order 'DHI type' observations
  - Quality factors can be used to modulate the R value (both positively and negatively)
- A straightforward intuitive and flexible approach that geologists can understand and readily use in risking discussions
- Final 'calibration' step is required