The Most Important Factors in Charge Risking and Best Practices*

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Search and Discovery Article #42015 (2017)**
Posted February 20, 2017

*Adapted from oral presentation given at AAPG Hedberg Conference, The Future of Basin and Petroleum Systems Modeling, Santa Barbara, California, April 3-8, 2016

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Abstract

The typical basin modeling evaluation in the industry is to construct burial and heat flow history (1, 2 or 3D) models of the basin, and in turn maturation of the source rock(s) based on detailed kinetic models. A choice migration algorithm along with assumption of migration along faults and other discontinuities are used to make sure oil (or gas) enters our trap. Finally, the volumes and type of fluids available for the proposed prospect are "predicted". Although arguments are usually around the sophistication of the methods, sensitivity and uncertainties of such a model, the prospect invariably looks good on the final presentation. The model matches maturity data from wells very well, and even the location of existing fields, so confidence is high. However, with all that effort, if we look back at the outcome of drilling these prospects in the last 20 of years, the vast majority of them (~70%) failed to find commercial hydrocarbons. For those that failed due to charge, there are simply three mechanisms, all related to migration: 1) Structure focusing, 2) Seal capacity and structure relief, and 3) Ultimate Expellable Potential (UEP) and migration loss.

Recognizing that these are the three main factors that control the possibility of a prospect receiving charge, our work would be more impactful if we could focus on evaluation of the factors, especially the ones with most uncertainty. Amongst the factors, the structure geometry and relief is usually better known and can be mapped, while seal capacity and migration losses are much less examined in the literature, when compared to such topics as kinetics and heat flow, which only partially address the volume expelled part of the second issue.

In recent years, we have developed a systematic approach to rank a prospect based on the probability of charge, by scenario testing of the key parameters within the likely range. These key parameters are rarely measured, but often can be calibrated indirectly with related observation in the basin we are working, and or geological analogs. When we deal with uncertainties in structure focusing, the role of faults can be unknown. By scenario testing whether faults can be lateral seals and scoring the prospects based on how many scenarios they do or do not receive charge, we may arrive at the likelihood of the charge probability.

When looking at the seal vs. structure closure mechanism, the geological model is first setup with the most likely seal capacity at each possible carrier level, and the migration model will either miss or charge our prospect. Then a number of scenarios of higher and lower cases of seal capacities are tested and in each scenario, the different prospects are marked either as charged or not charged. This would lead to a probabilistic view of the prospects, and the prospects that receive charge in most of the scenarios will be ranked higher. If a prospect cannot get charged with reasonable range of seal capacity assumptions, it is deemed very high risk. Similarly, scenarios of migration losses can be used to assign charge probabilities to prospects. The source rock input, kinetics and thermal history also play a part in this exercise, but in most cases, the overbearing control is migration loss. It is especially so when the source rock has a lower UEP, or less mature. The scenarios can also be constrained with the spatial distribution of known accumulations and their fluid types, as well as dry holes that may confirm charge failure.

Reference Cited

Kothari, V., B. Naidu, V.R. Sunder, J. Dolson, S.D. Burley, N.P. Whiteley, P. Mohapatra, and B. Ananthakrishnan, 2015, Discovery and Petroleum System of Barmer Basin, India: Search and Discovery Article 110202, Web Accessed February 12, 2017, http://www.searchanddiscovery.com/documents/2015/110202kothari/ndx_kothari.pdf.

AAPG HEDBERG CONFERENCE
THE FUTURE OF BASIN AND PETROLEUM SYSTEMS MODELING
APRIL 3-8, 2016 — SANTA BARBARA, CALIFORNIA, USA

The Most Important Factors in Charge Risking & Best Practices

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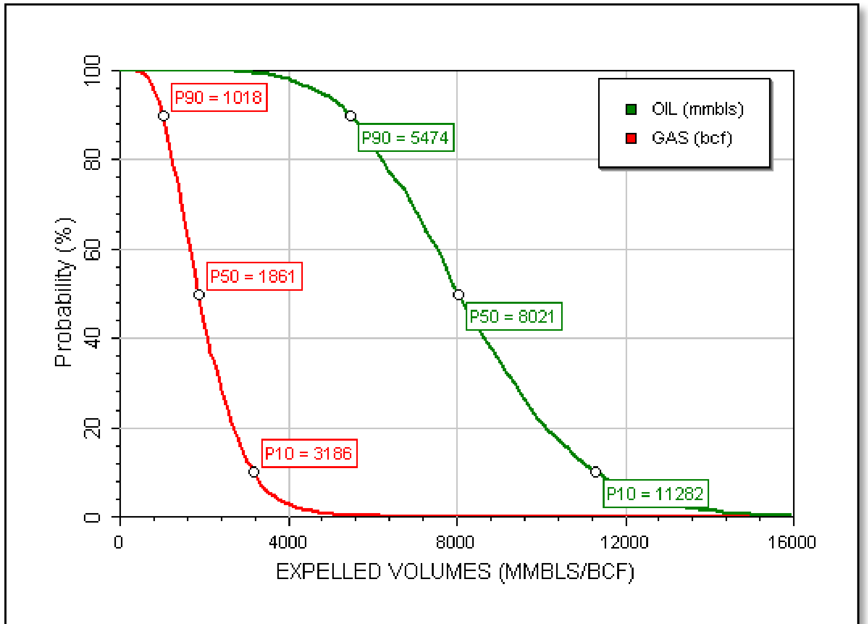
Uncertainty in Estimating Charge Volumes and Fluid Type

THINGS WE DO NOT KNOW		THINGS WE SPEND TIME ON
TOC, HI, Thickness, NTG in the kitchen	Generation	Kinetics, Tmax, Ro, heat flow, thermal conductivity, lithology, compaction parameters …
Adsorption capacity vs fluid properties expulsion fractionation	Expulsion	Adsorption
Porosity, saturation, Inter-beds, heterogeneity, seal capacities fractionation	Primary Migration	??
Fetch area, thickness, porosity, saturation, Inter-beds, heterogeneity, juxtaposition, traps and micro -traps, faults, seal capacities	Secondary Migration	Darcy vs IP
	Charge	

- Things we do not study much cause the biggest uncertainty.
- Biggest overall uncertainty is primary and secondary migration losses, and second is probably source rock type, volume, quality and distribution in the kitchen.
- Expulsion and migration fractionation process cause fluids trapped in reservoirs to be very different from what is generated.

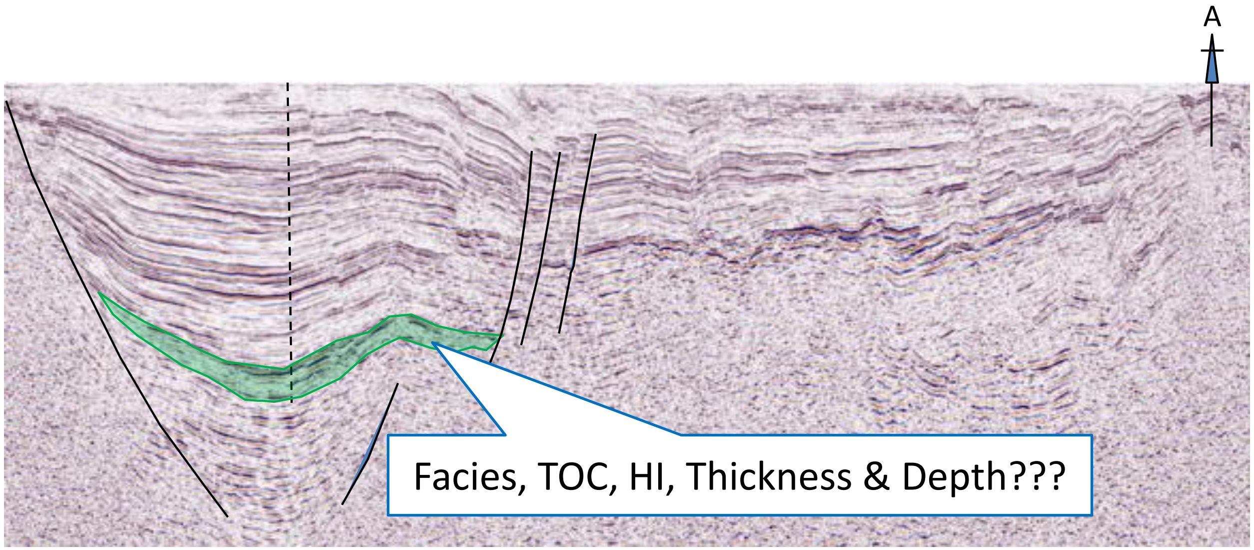
Typical Uncertainty in Expelled Volumes



Parameter	Range
TOC	± 1%
HI	± 100mg/g
Kinetics	± 10°C
Temperature	± 10°C
Fetch area	± 10%

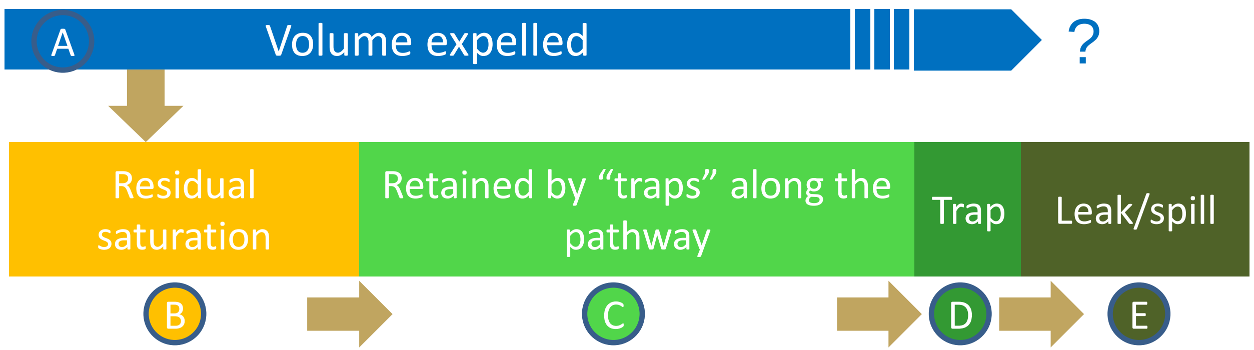
- ❑ Modeled expulsion volumes from undrilled kitchen in a well studied area. The range of P10/P90 is about a factor of 2.
- ❑ In new ventures, this uncertainty is easily an order of magnitude
- ❑ Often most of this uncertainty comes from not knowing source parameters in the kitchen.

The Typical New Venture Modeling Problem



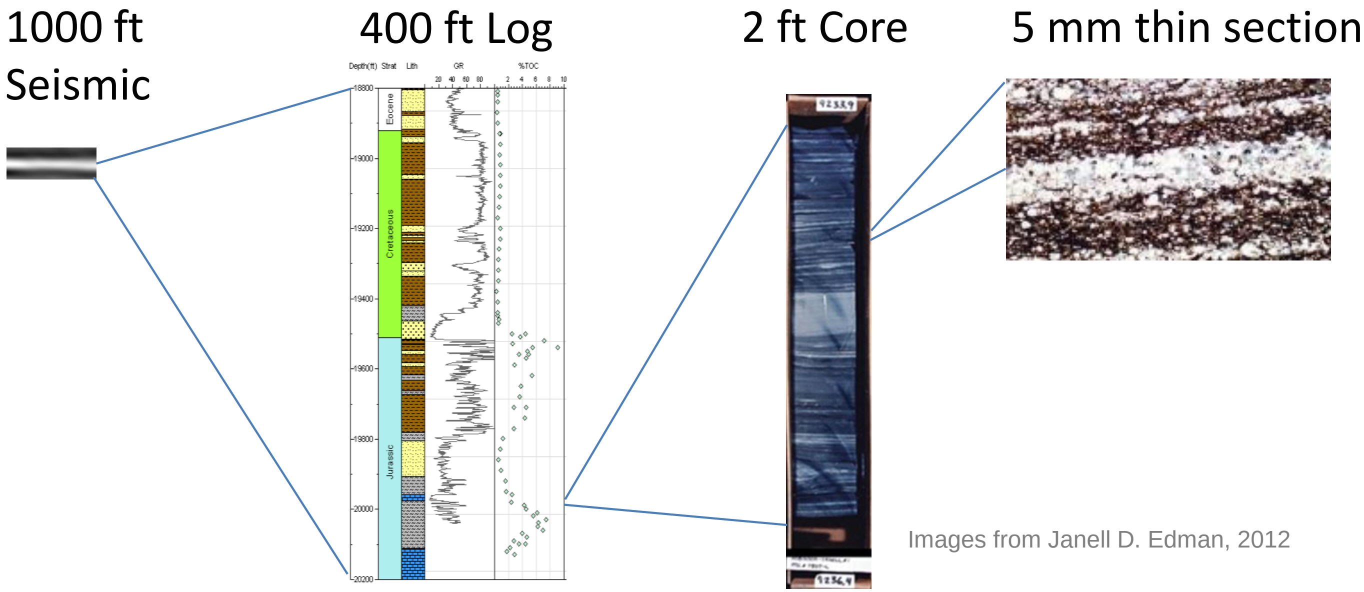
- Well A penetrated a 50 meter section with TOC 2-3% and HI of 150-300 mg/gTOC (type II/III). Calculated UEP is 5 mmboe/km2. Should I use these numbers in my software to model the source kitchen?
- Can the source rock be 6% TOC, 600 HI and 100m? Then UEP is 60 mmboe/km2 ie. 12 times the volume than if the numbers from the well are used.

Charging Order of the Migration Process



- Available volume, expelled from kerogen after satisfying adsorption, will first need to saturate pores within and near the source rock (B, unconventional) and then fill the migration paths (C, micro/macro traps and residue saturation) before reaching the trap (D, our prospect). If trap is filled, then leak or spill occurs (E).
- If volume expelled is less than B + C, our trap is not charged. This is a high probability when source rock is average or weak, or the target trap is up dip or shallow.
- Probability of half filling our trap is small as the expelled volume has to be just more than B + C, but less than B+C+D. Don't worry about your trap is full or not, worry about if it will be filled at all.

Retained Volumes: Limitation of Data & Uncertainty

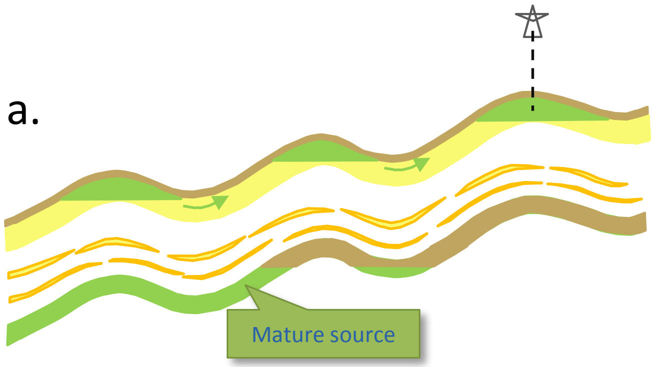


Images from Janell D. Edman, 2012

- ❑ Retained volumes depends on the <u>heterogeneity and structure complexity</u> of the source and carrier beds.
- ❑ Most of that is below seismic resolution, and even log resolution.
- ❑ For example, 10% saturation over 200 meters retains 10 mmbls/km2
- ❑ Eagle Ford (core and thin section) retains ~50% of the hydrocarbons generated (~15 mmbls/km2 over 30 meters).

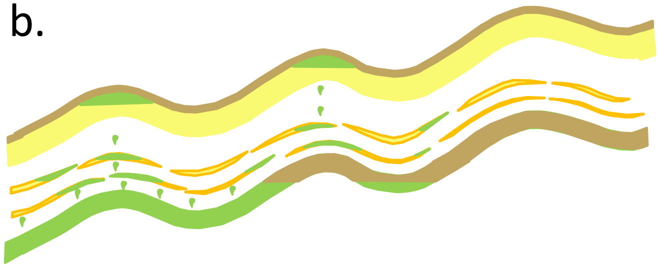
The Only Two Ways a Trap is not Charged

a.



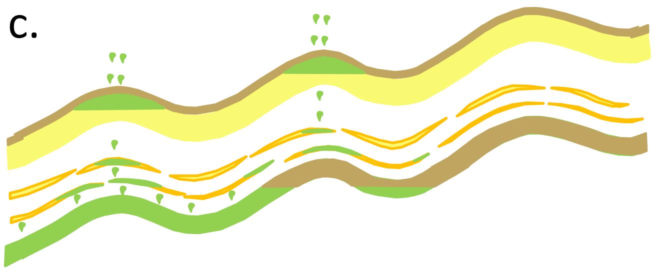
- This is a very simple situation where a model shows that the intended prospect will be filled with oil. How Can this be wrong?

b.



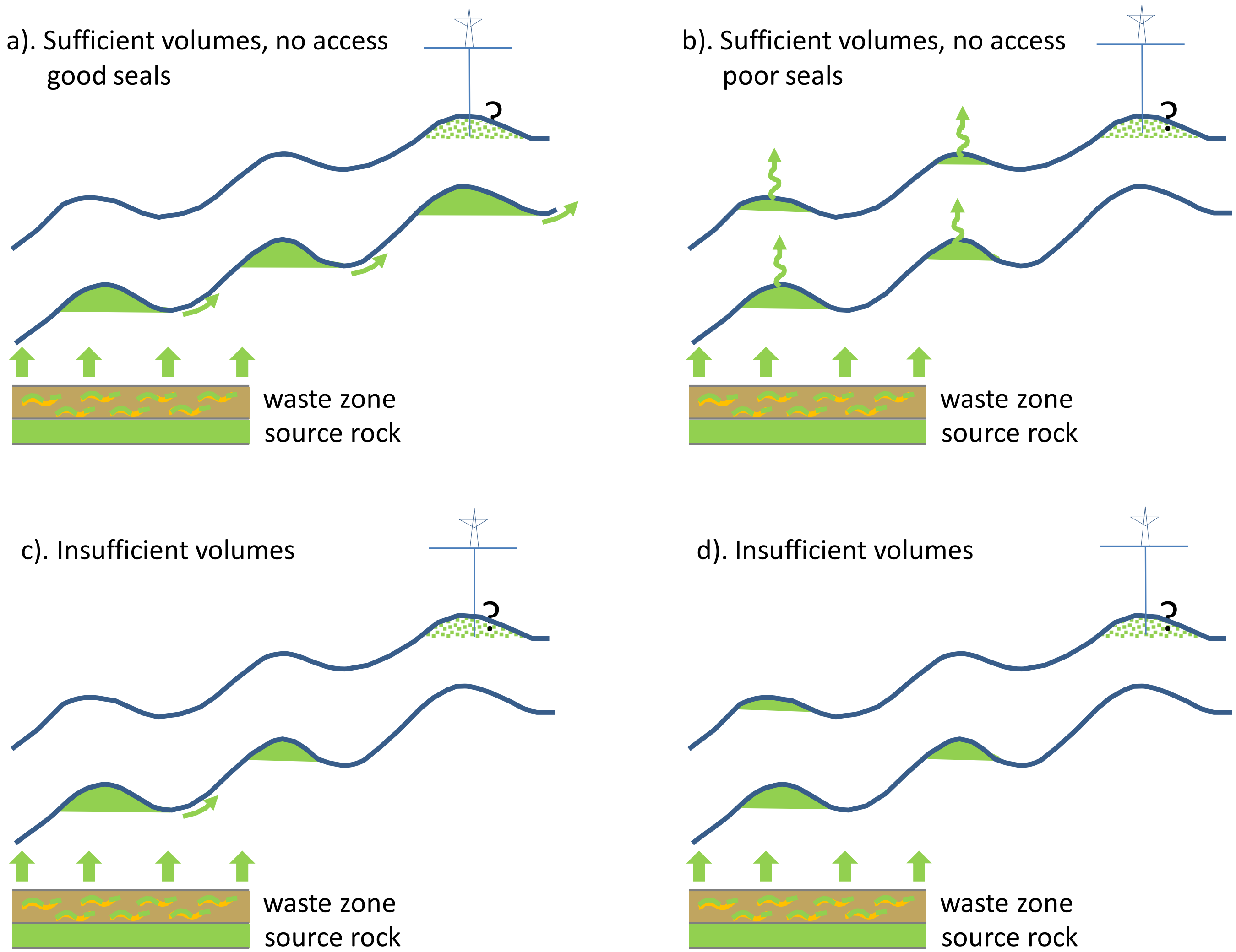
- Well, in this scenario, the source rock, the zones above it, and the traps (known and unknown) down dip retain (migration loss) more volumes than is generated, the oil does not reach the prospect.

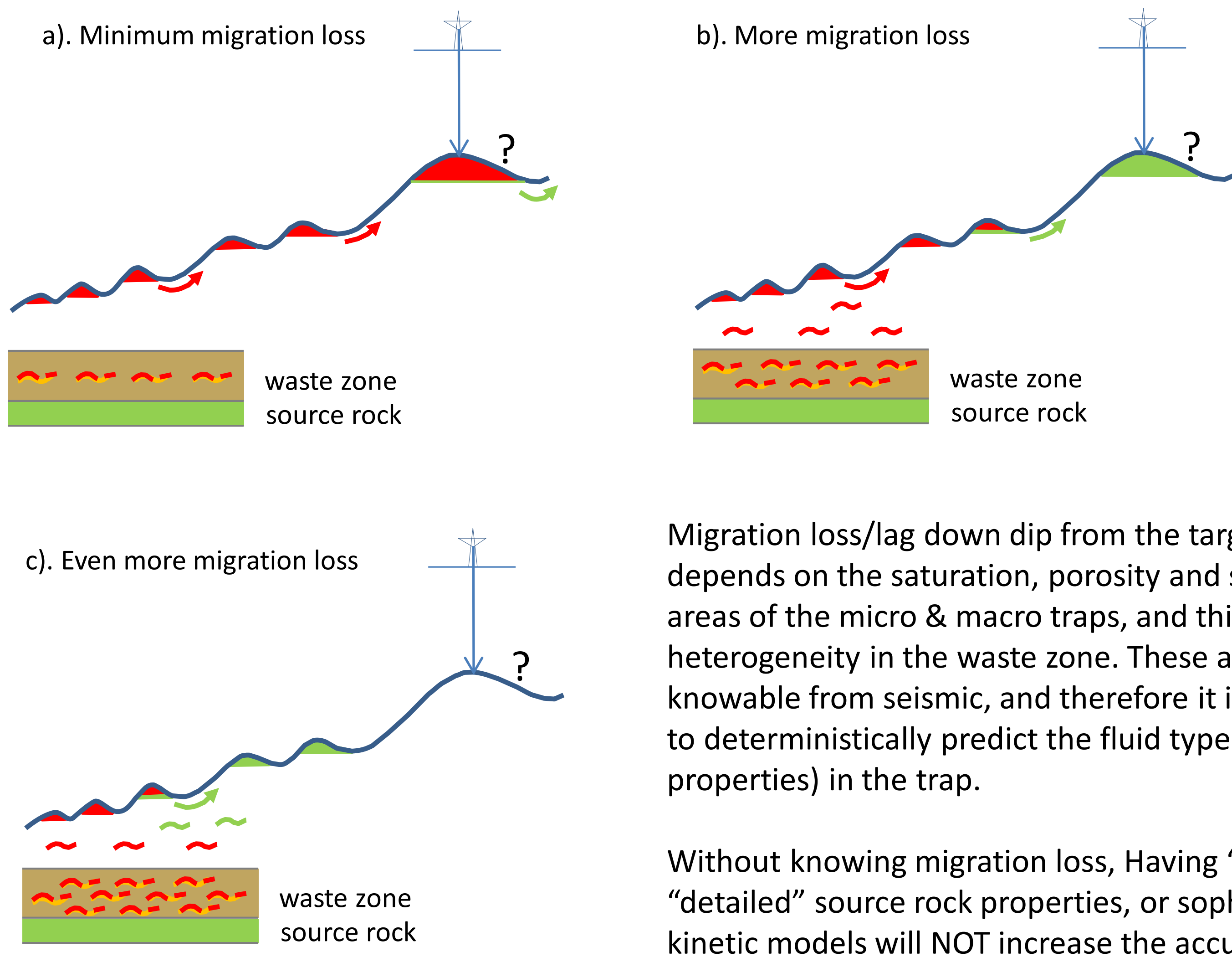
c.



- Another possibility is that the seals at the down-dip structures may allow the oil to leak rather than spill into our trap.

What Are the Controlling Parameters?





Migration loss/lag down dip from the target trap depends on the saturation, porosity and sizes and areas of the micro & macro traps, and thickness and heterogeneity in the waste zone. These are not knowable from seismic, and therefore it is not possible to deterministically predict the fluid type (or properties) in the trap.

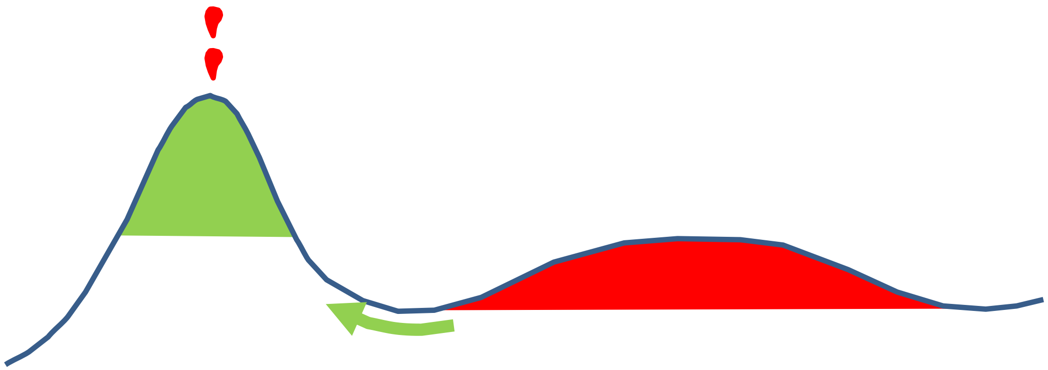
Without knowing migration loss, Having "accurate" and "detailed" source rock properties, or sophisticated kinetic models will NOT increase the accuracy of prediction.

The Only Two Ways a Trap is not Charged

1. Volume Expelled versus Volume retained/lost determines if there is enough to reach the trap.

2. Seal capacity versus structure closure & geometry determines vertical/lateral migration and if HC can reach the trap.

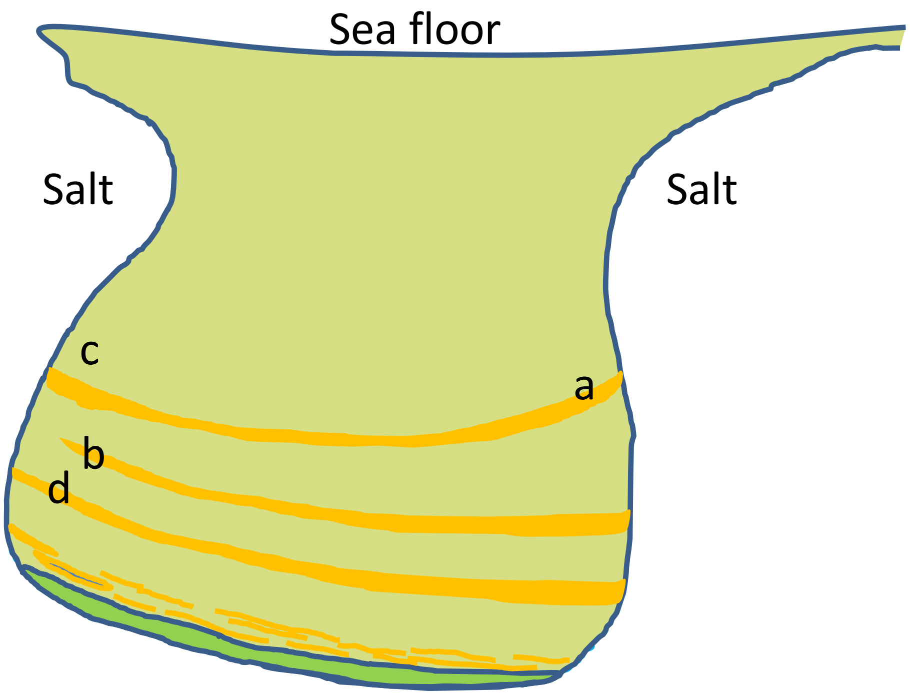
How Seal Capacity Can Control Fluid Type



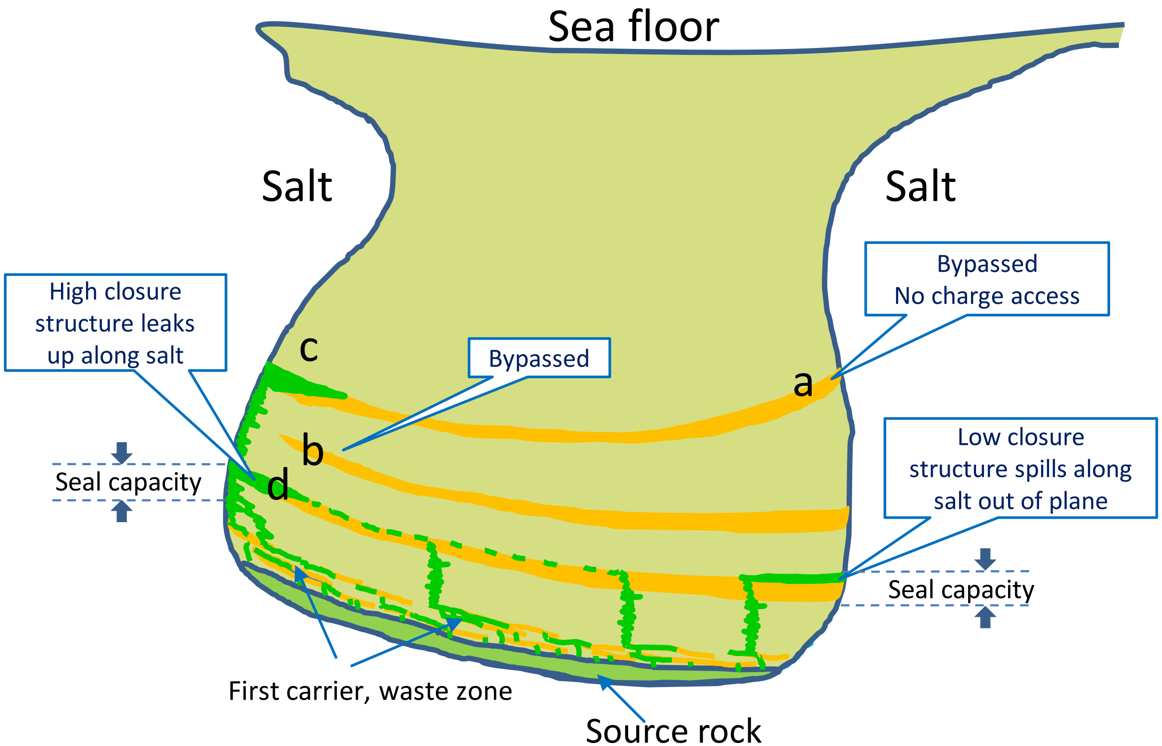
- In a dual phase environment, taller structures (closure>Pc) may likely trap oil and low relief structures (closure<Pc) retain gas --- John K. Sales 1997.
- What seal capacity do you assign in your model, and what is an appropriate seal capacity?
- Seal capacity is a function of pore throat size, fluid densities and interfacial tension (IFT). Can we measure these on seismic ?

Best Practice:

What are the factors that may prevent charge to the prospects? And only using seismic data, which one of these have the highest/lowest risk?

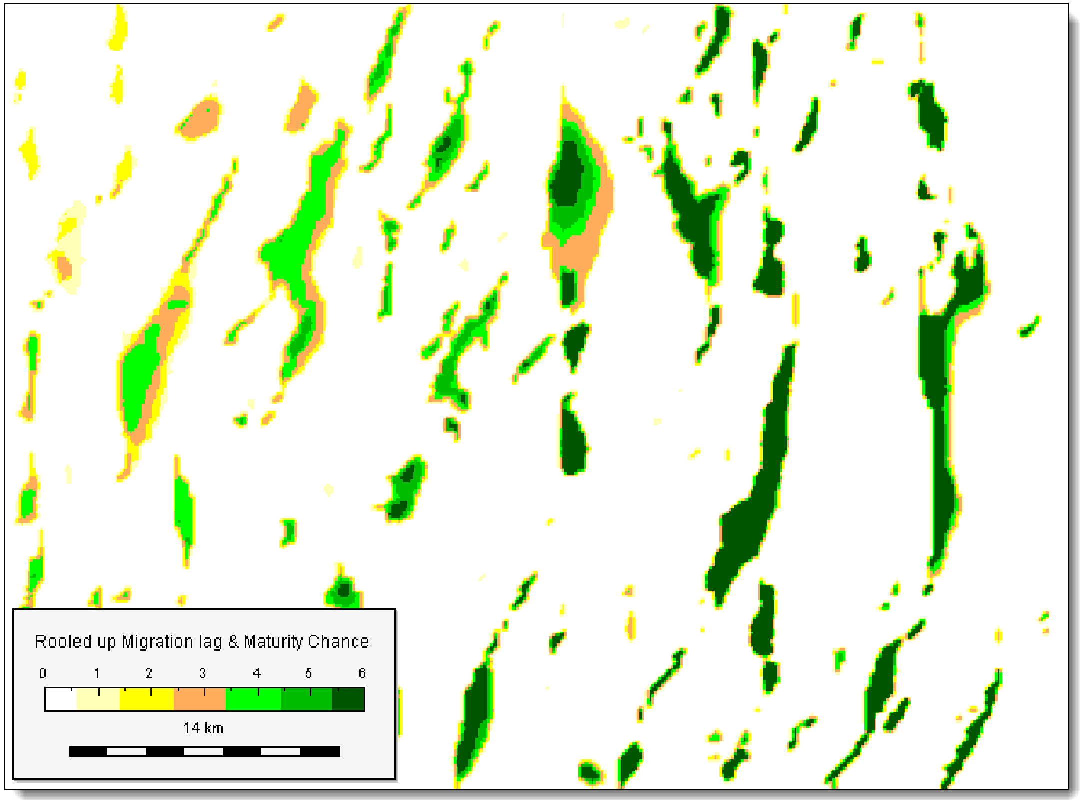


Best Practice:
Bottom up Charge Access Analysis – closure vs seal capacity



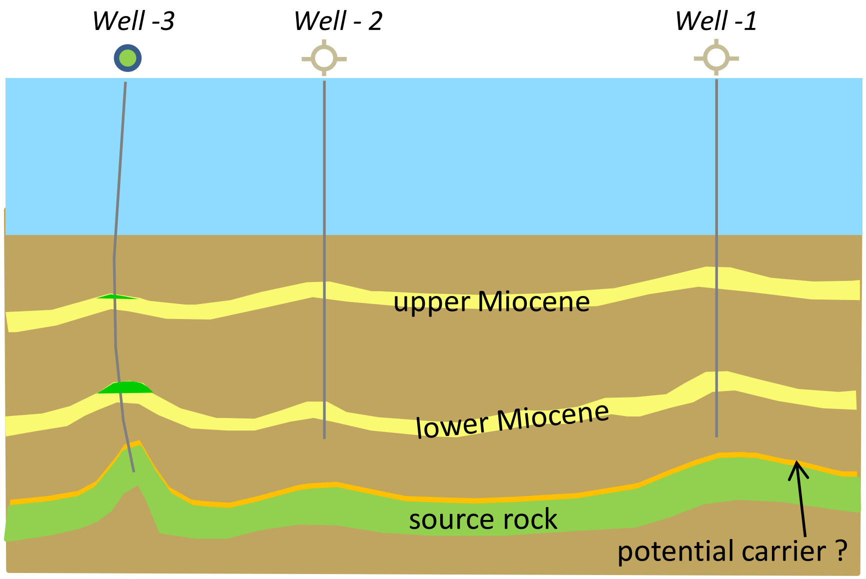
- Seal capacity versus structure closure analysis example, Gulf of Mexico. Trap a may be a large structure, but the highest risk for charge access. Traps c and d are lower risk. Trap d is lower risk for volume needed as well. Trap b is similar to a.
- Running scenarios of seal capacities will provide a risk factor for each trap.

Best Practice:
Risking migration loss/lag & and expelled volumes

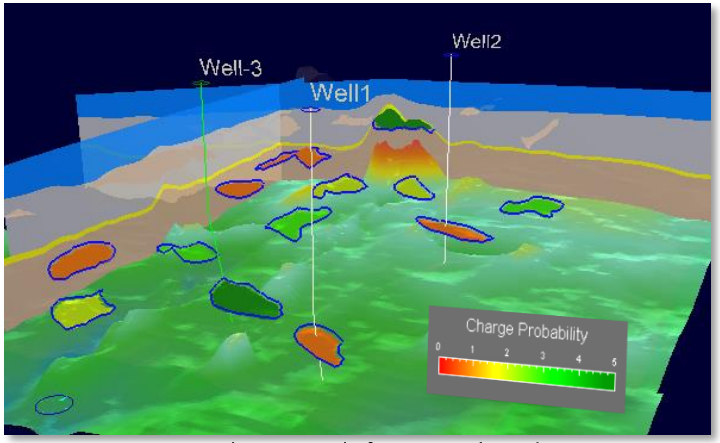


Because of uncertainty in expelled and lag/loss volumes, there are too many possibilities for any deterministic model to provide the right answer. One of the approaches we take is to run different scenarios of migration losses (lag) source rock potential. Compiling the results as a "charge risk" map shown here using Trinity software developed by ZetaWare, Inc. The structure closures with darker green color indicate they are filled in more of the scenarios. Light Yellow to light green colored structures are less likely to receive charge.

Best Practice:
Bottom up Charge Access Analysis – closure vs seal capacity



Based on an offshore West Africa basin

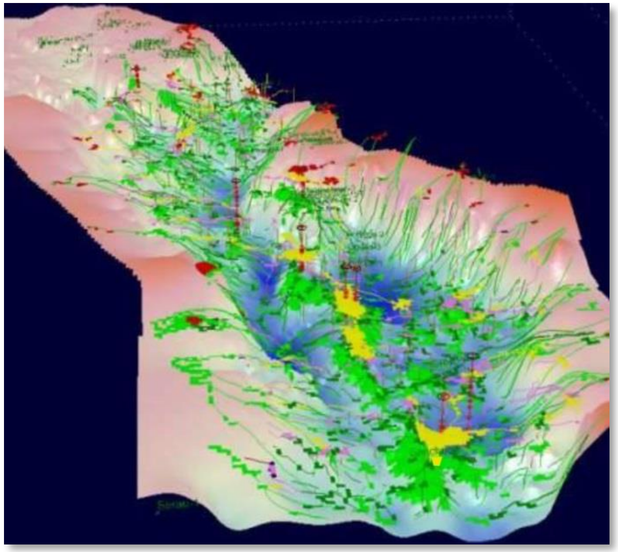


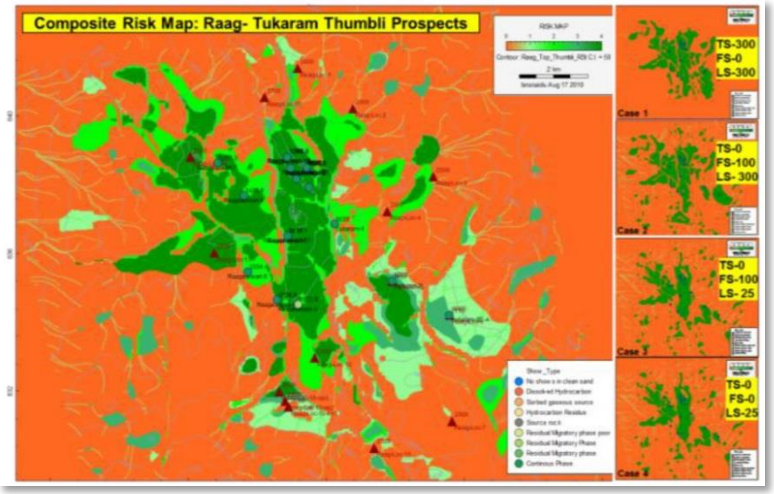
Lower Miocene charge risk from seal and source scenarios. Red high risk, dark green low risk.

Running multiple scenarios of top seals at the potential first carrier level allow charge risk to be assigned to Lower Miocene prospects. Higher structure relief at the first carrier level increases the chance of charging the prospects. Source rock presence, maturity and migration loss risk can be rolled into the results as well.

Wells 1 and 2 are dry holes and well 3 is a discovery.

- Another Migration Risking Example

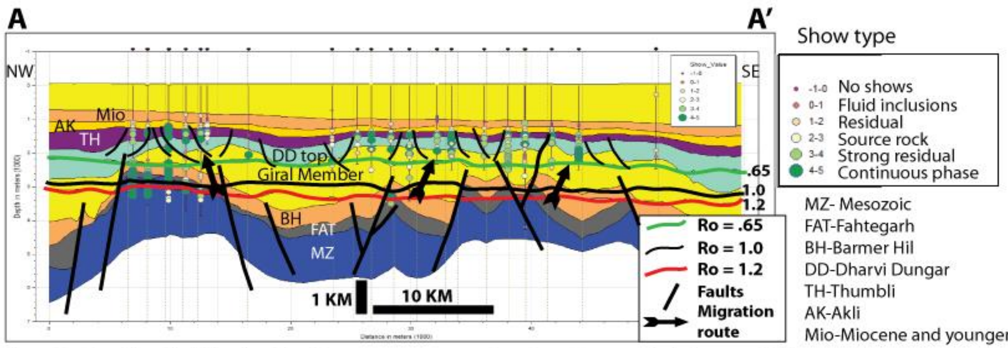




Multiple top and lateral seal scenarios help high grade prospects around known fields.

Vachaspati Kothari1 et el, AAPG Search and Discovery Article, 2015.

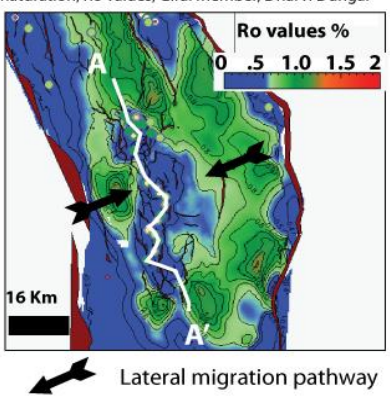
Best Practice:
Integrating Spatial Fluid Data, Top Down Analysis



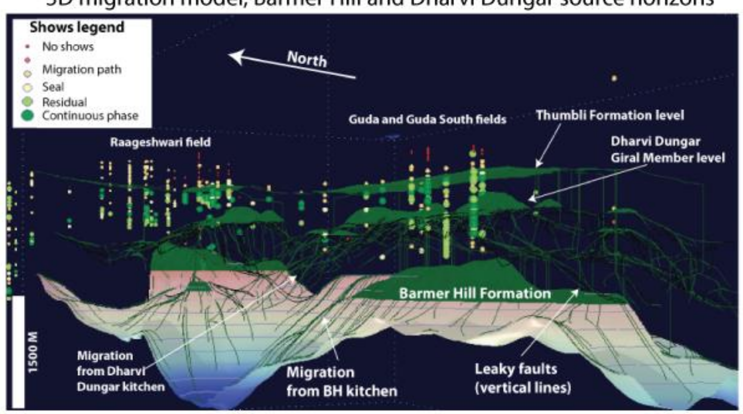
Migration front at TH (purple) constrained by discoveries and show database

John Dolson, 2015

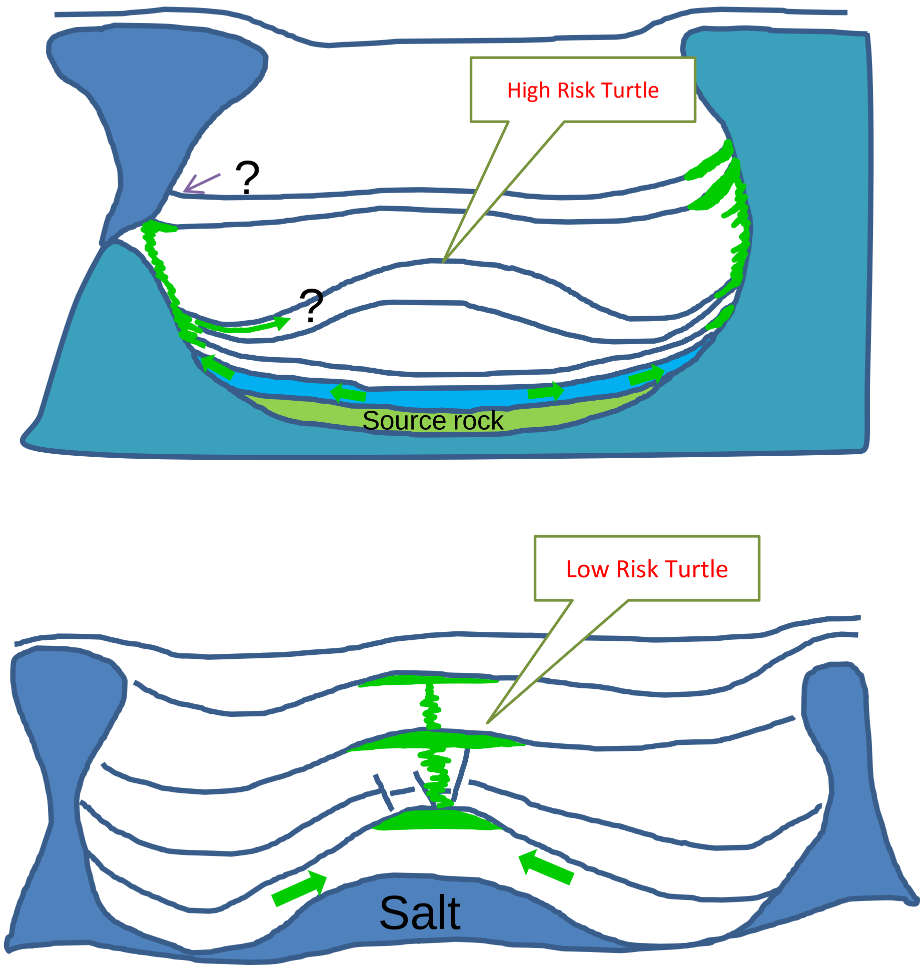
Maturation, Ro values, Giral Member, Dharvi Dungar



3D migration model, Barmer Hill and Dharvi Dungar source horizons



- Integration of fluid data (fields, fluid type, column heights, properties, shows, gas isotopes, dry holes) help constrain seal capacities, as well as migration front.
- Scenarios that explain the fluid data better are assigned higher weighting.

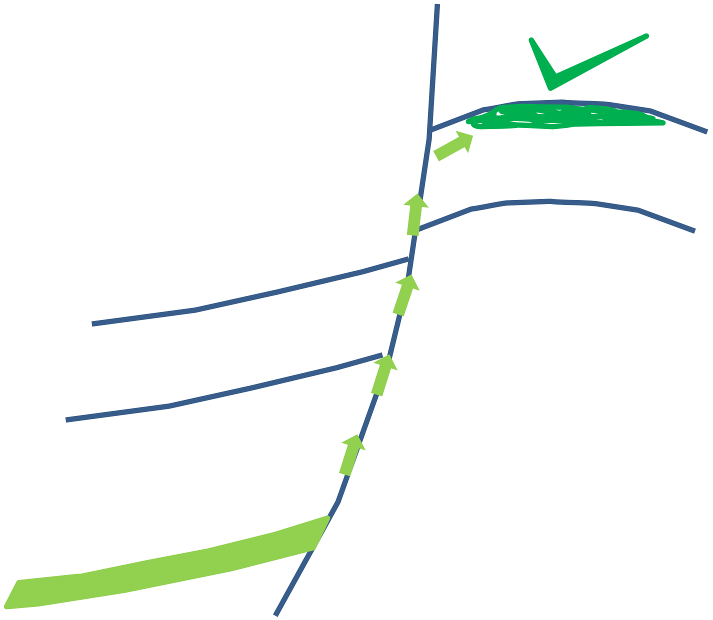


Not all turtles are created equal.

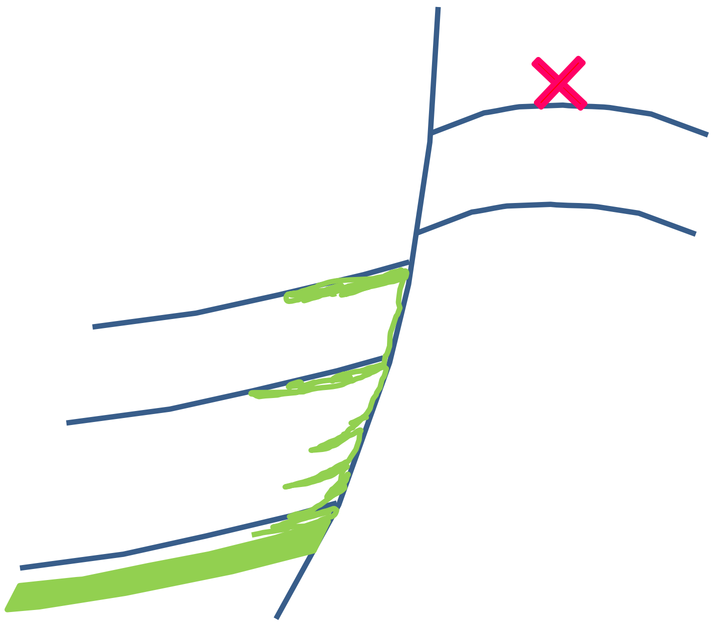
Turtle structures with a de-focused bottom is riskier than those with a salt pillow below.

Some may still work as there may be a probability of migration back into the structure from 3way closures around the turtle structure, especially if the 3ways are low relief so they are less likely to leak up.

One of the most common way to use a basin model is to draw migration arrows up the fault to charge the prospect. But that is the least likely to happen, and many dry holes are drilled this way.



Popular model often lead to a dry hole



Charge access analysis tells us to drill the down thrown side.

Conclusions:

- ❑ We have the first principles to make these predictions, but we do not have the subsurface resolution (geometries, heterogeneity and parameters) required to predict trap content – Richard Bishop.

- ❑ A deeper unknown carrier bed, or unresolved structure or stratigraphic features may cause the migrating fluids to divert from our prospect.

- ❑ Volumes expelled may not be enough to overcome migration losses, and fill deeper micro and macro traps – to reach our prospect.

- ❑ The two most important parameters – seal capacity/structure closure and expelled volume/migration loss -- are not measurable on seismic.
- ❑ Best practice includes:
    - Scenario risk modeling – migration risk map.
    - Bottom up charge risk analysis – seals vs closure
    - Integration of spatial fluid data for top down analysis – scenarios that fit the fluid data spatially are lower risk.