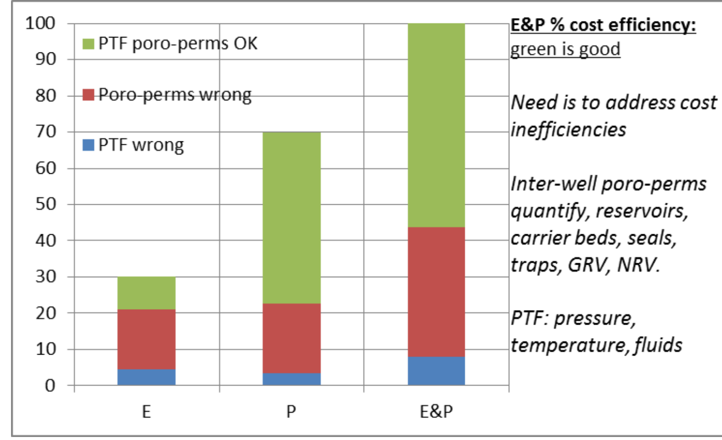
How geo-detectives drive

Seismic Geo-Petro Normalisation

30 minute presentation: how to

- Double geo- petro information in seismic.
- Cut in E&P cost & risk >10%, >$5/b to be saved.
- Drive quantitative interpretation

Rule based **E**xpert systems **IT**

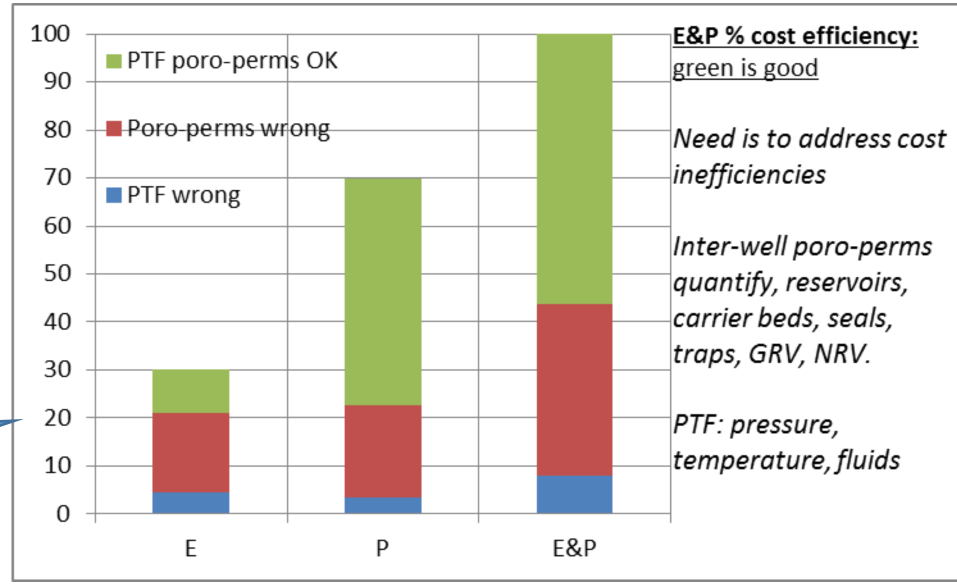


Problem

- E&P investment is constrained by
  - Low oil price & investors acting as if 'peak oil' is not imminent.
  - Low investor confidence, concerning E&P efficiency.
    - Rules & tools made for E&P of large, simple, conventional traps that are inefficient for E&P of remaining small, complex traps.
- 37.5% of E&P cost is wasted by poro-perm forecasts.
  - Poro-perm (holes & connection) mapping is risk dependent upon inter-well lithology mapping. We have to better quantify geology.
  - Exploration, ¼ of E&P cost; ¾ of this- wrong inter-well poro-perms.
  - Production, ¾ of E&P cost; ¼ of this- wrong inter-well poro-perms.
- E&P managers and investors need evidence that
  - We can double & integrate inter-well geo- petro information
  - Doubled G&G resolution makes E&P 15% more efficient.
  - Soon, supply and demand will sustain higher oil price.
  - Increased E&P funding is economically appropriate, now.

Cost Analysis

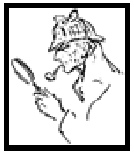
E&P spends $50/b x
100Mb p.d.
$5B per day.



Per $100 spent in E&P, >$35 generates no value, by errors forecasting inter-well poro-perms (i.e. risk dependent on lithology, as velocity is already low risk). This equates to $1.75B per day. Geo-normalisation relatively doubles inter-well data, at 12.5m3m, irrespective of field size.

Oil companies should be able to convert $15 of this >$35 wasted cost, per $100, to value. This equates to $0.75B per day. This allows more than adequate margins for service provision to E&P staff of rules and tools necessary to deliver this cost benefit.

GeoDirk IOM Ltd offers to serve a 1st user group of 5, each committing 3 projects p.a. at £50k. The group then fine tunes existing Dbases, algorithms, apps, to enhance 1st user advantage.



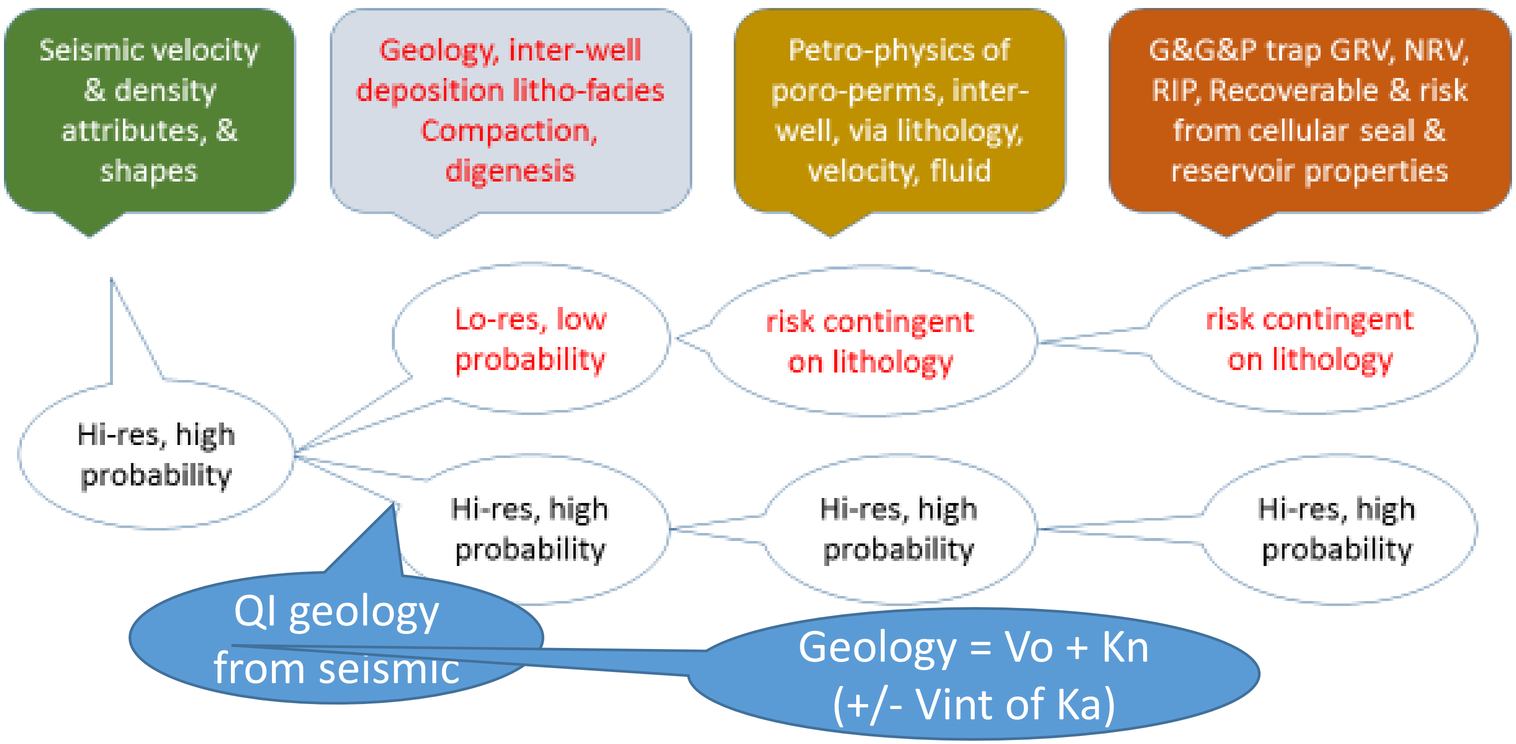
Overview

- E&P in 2015 costs some $60/b. 1/3rd of this, $20/b, is on average, cost wasted by wrong poro-perm mapping, (rock holes & connections).
- If all sediments compacted similarly, then poro-perms would be mapped at much less risk, since
  - Time, velocity and depth are quantifiable with low risk.
  - Lithology (with few exceptions) is a low risk function of depth & velocity
  - Poro-perms are a low risk function of velocity & lithology.
- Geo-normalisation, (quantitative interpretation) uses
  - Data-bases of user defined ‘normal depth’ poro-perms, per lithology per velocity, in normal fluid pressure and temperature.
  - Means to separately define sequence volumes having similar burial/ digenesis controls, & any depth shift ΔD needed fit ‘norm’. (Risks).
  - Means to process stacked 2-4D seismic samples (2 to 4ms) via spatial models of ΔD, AI changes to Vint to depth to lithology to poro-perms.
- You drive QI processing, from / to your workstation & add skills, fast.
- To double risk relevant information, thus probably save >$5/b, contact www.geodirk or www.geoleum.
- A few team users in Scotland + state support = local service centre.

The missing link

sensible poro-perms derive from sensible geology.

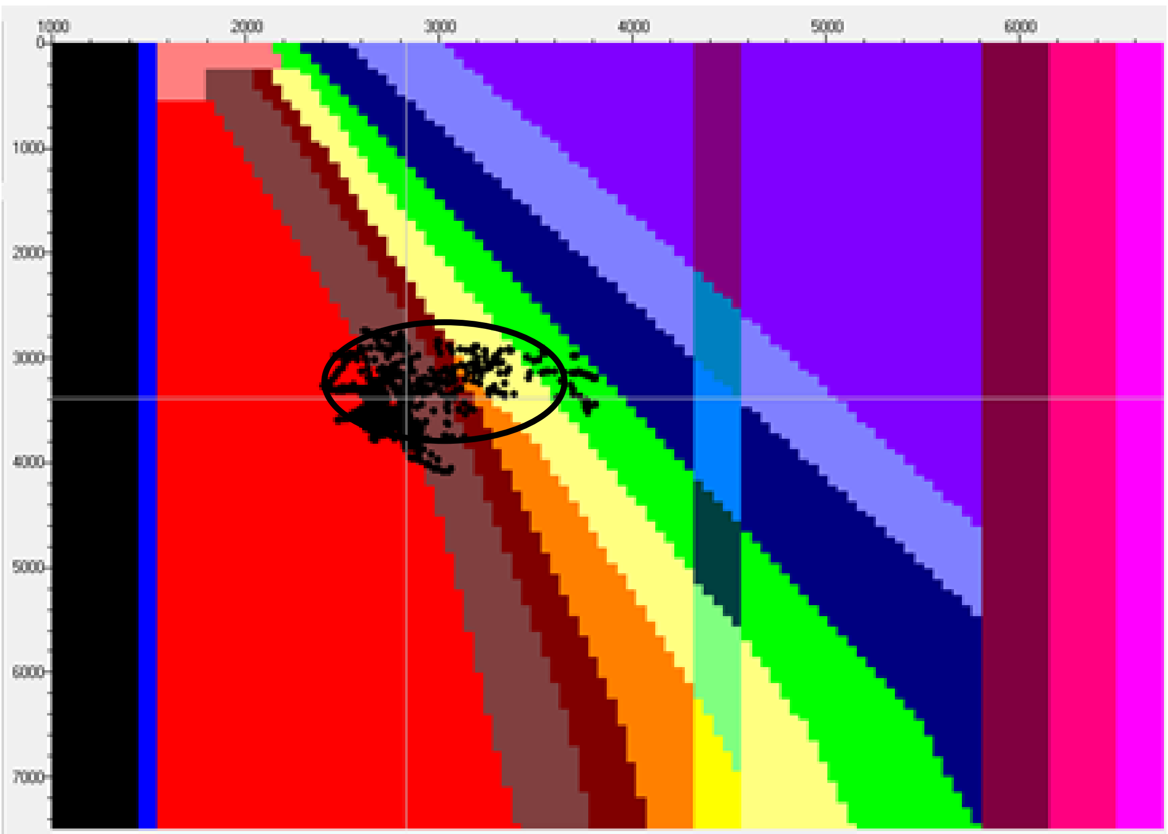
One missing link, causes most of E&P inefficiency



Inter-well poro-perms, contingent on lithologies.

- G&G asset teams work seismic into as many poro-perm models as geologic models used to drive processing.
  - G&G need better rules & tools to work seismic into lithology.
    - This mattered little, when prospects were bigger & of lower risk.
- Geo-normalisation helps teams integrate Geology & Petrophysics from seismic @ 12.5m3.
  - Each discipline drives their part of work flow, becoming expert users of **R**ule based **E**xpert **IT** systems, to sensibly process seismic to geology & poro-perms @ 12.5m3.
  - It takes you a few weeks to work a project data set, this way.

Define/ lithology, normal burial in Velocity / depth domain. Define associated porosities & permeabilities. Then, quantify depth shift up or down to adjust local rock volumes to normal.

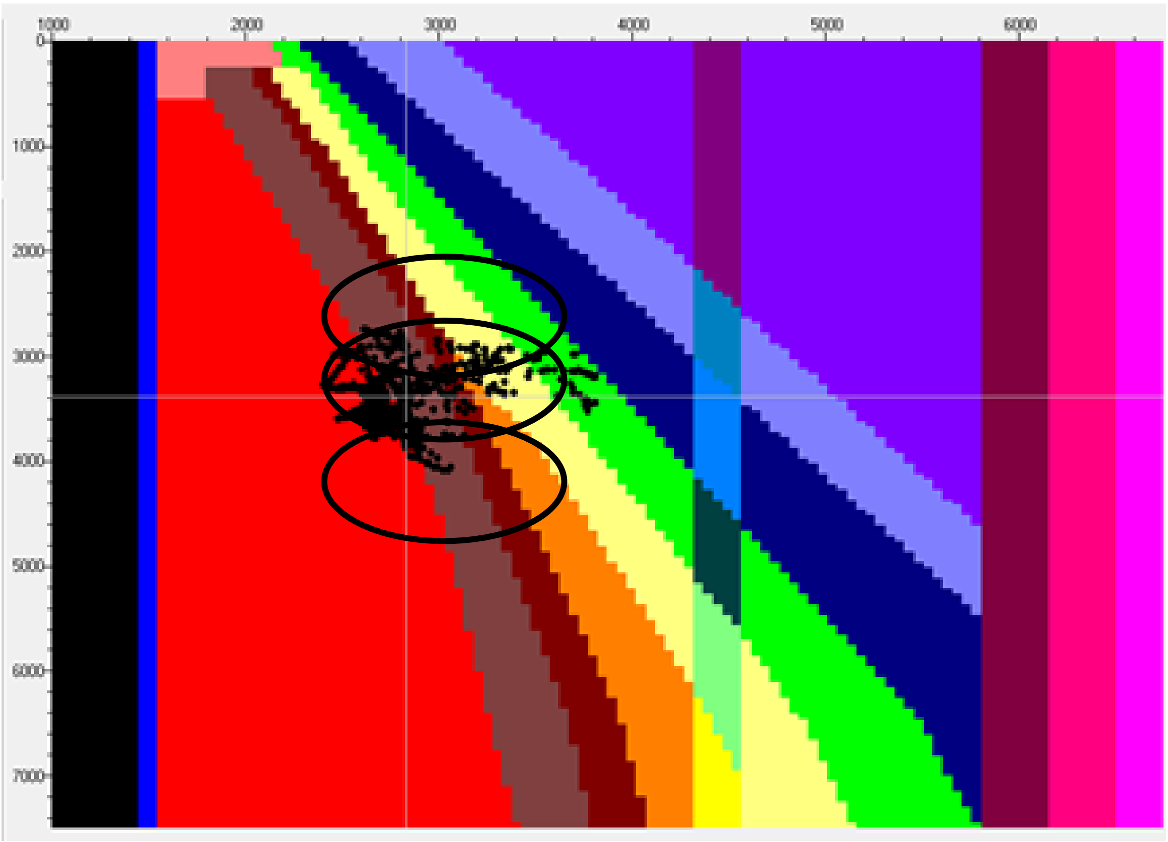


The centre sequence looks like spanning inter-bedded o/p shale to sand to carb rich clastic.

Where compaction occurs like this, any point on the chart can be defined by a velocity Vo + K line & depth

Shale compacts slower than sand which compacts slower than chalk.
Salt, evaporates don't compact (K is 0m/s/m)

Define/ lithology, normal burial in Velocity / depth domain.
Define associated porosities & permeabilities.
Then, quantify depth shift up or down to adjust local rock volumes to normal.

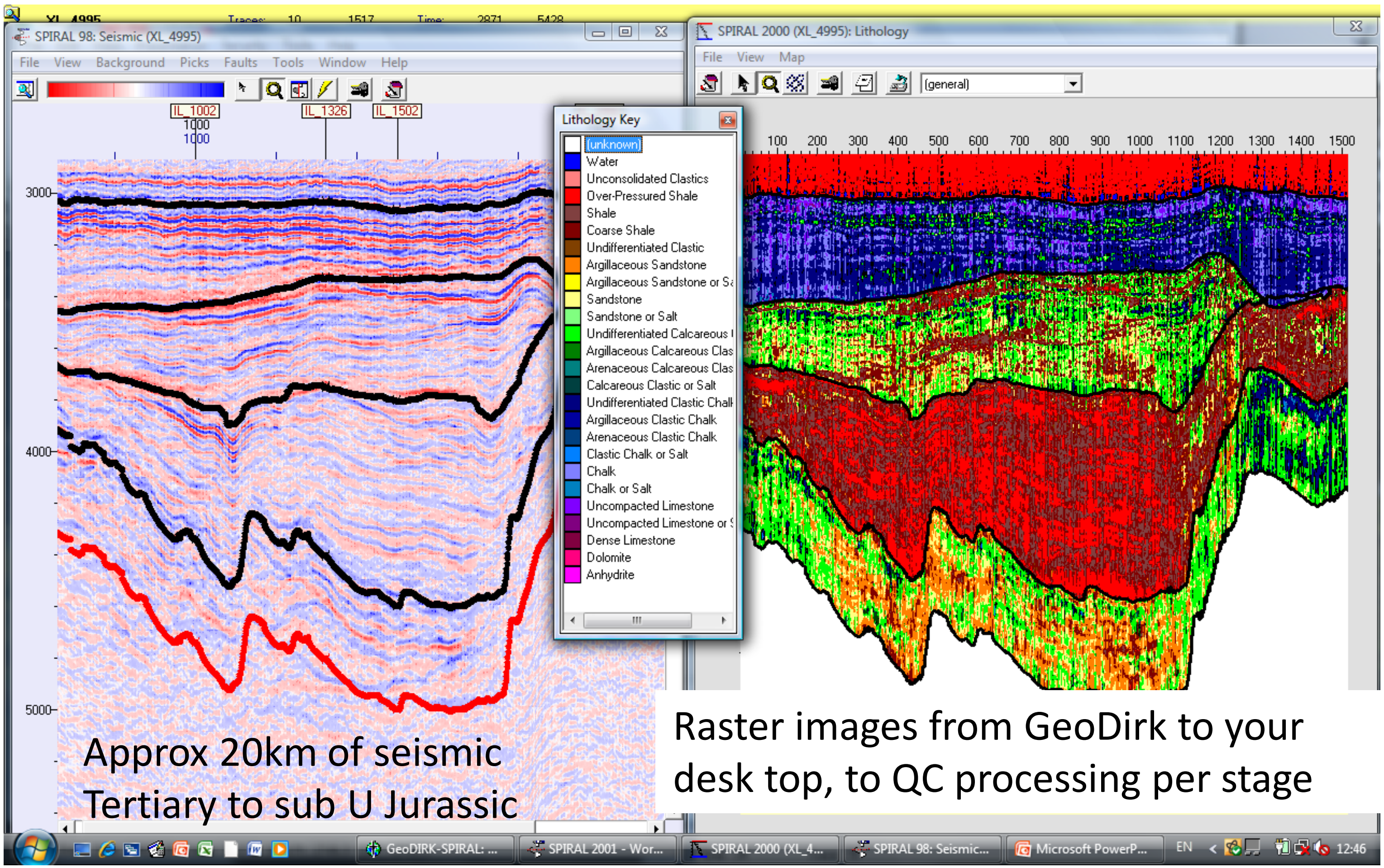


If normalisation shift is down, (adjusting for inversion, non vertical stress etc), the lithologies change (finer clastic).

If normalisation shift is up, (adjusting for deep water, o/p, slope vectoring etc), the lithologies change (coarser clastic).

Any point on the chart can be defined by a velocity Vo + K (+/- depth shift of KA, abnormal compaction & present depth

Your ‘normal burial D-base’ & QI of ΔD all sequence cells, allow trace sample conversion to lithology. We’ll come to that.
If it looks sensible, it probably is. If not, find out why & amend.



Approx 20km of seismic
Tertiary to sub U Jurassic

Raster images from GeoDirk to your
desk top, to QC processing per stage

Key tools for expert drivers of ‘seismic geo-petro normalisation’

- Dbase 1, velocity domain: per lithology,
  - Porosity & permeability per fluid. Most companies already have this.
- Dbase 2, depth domain: normal shelf compaction
  - Per lithology, velocity, poro-perms per fluid.

Start projects with DBase2, holding all possible lithologies/ sequence. Don’t start with just local well data.

- App’s, DBases to work seismic shapes, attributes to separate volumes
  - Sharing similar compaction /digenesis in burial, / lithology
    - Normal +/- separate & net effects of water depth, non vertical stress/ strain, basin or salt inversion, o/pressure, faulting, igneous, mechanical strength, age, temperature, conductivity, etc.
  - App’s to define ΔD shift, local to normal burial depth / cell
- App’s to quantify / 2ms sample trace, normalised
  - AI, Vint, compaction Knormal, ΔD of Kabnormal by each risk,
    - & then net abnormal compaction / cell.
  - Then Lithology, porosity total, permeability,
  - Then seal, reservoir, carrier bed properties
  - Then seal base GRV, fluid substitution/ trap, gross & net rock volume

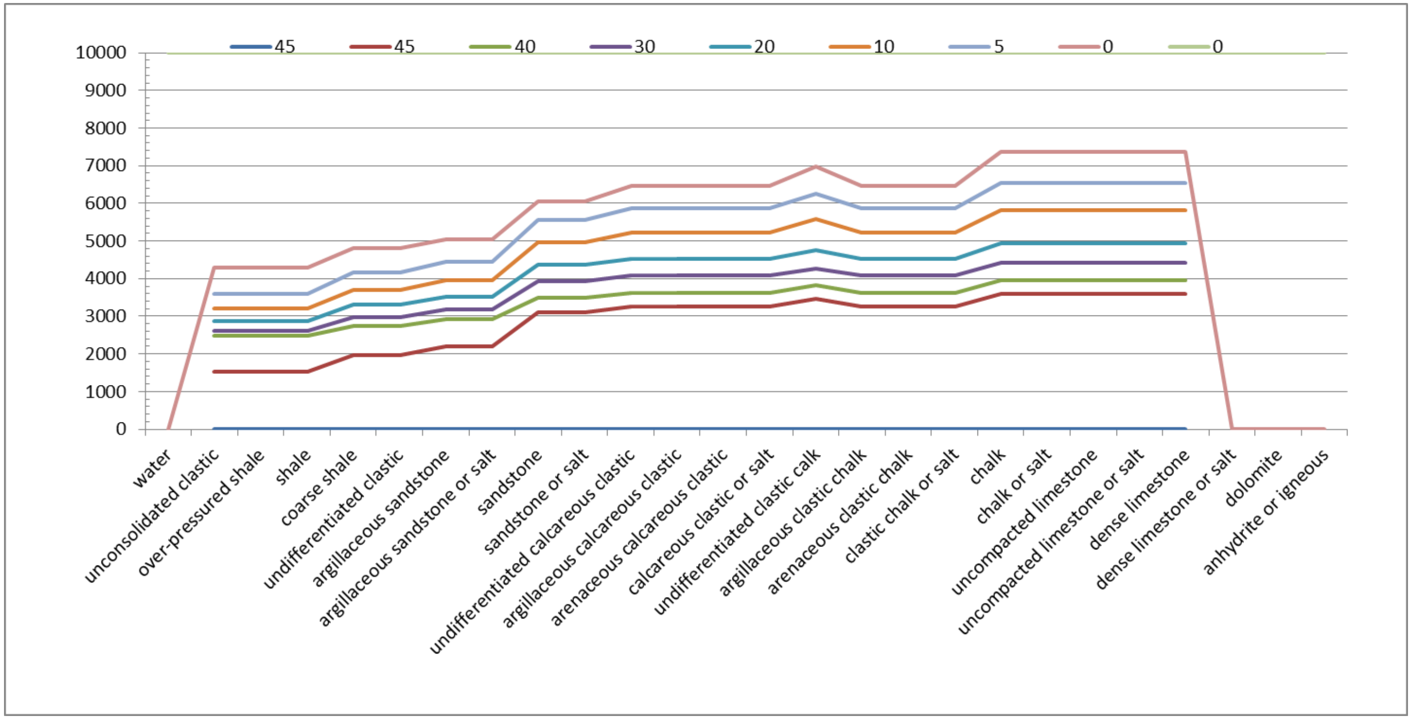
©	Burial Changes, re Normalisation
CONVA	*Conva: non vertical stress adjusted*
SINVA	*Sinva: structural inversion s/w adjusted*
BINVA	*Binva: structural inversion l/w adjusted*
FANVA	*Fanva: fault adjusted*
WANVA	*Wanva: water depth adjusted*
LINVA	*Linva: fluid adjusted*
PENVA	*Penva: pressure adjusted*
TENVA	*Tenva: temperature adjusted*
SHENVA	*shelf*
SLONVA	*slope*
ANVA	*Anva: age adjusted*
DENVA	*Denva: overburden density adjusted*
COLINVA	calibrated lithology normalised depth

Driving G&G&P seismic normalisation

- Pick all sequences in time
  - Relatively homogeneous litho units, separated by unconformities of correlated conformities.
  - Load well & seismic velocities, depth conversion 1
- Pick / sequence, well data: time, velocity, depth, poro-perms, fluids, pressure, temp, mechanical strength.
  - Define depth difference / sequence. to tie well data to generic normal compaction rock properties. Grid.
- Separate rock volumes with similar compaction /digenesis
  - Quantify normal +/- separate & net effects of water depth, non vertical stress/ strain, basin or salt inversion, o/pressure, faulting, igneous, mechanical strength, age, temperature, conductivity, etc.
  - Per rock volume of similar burial change causes, define ΔD to fit normal.
- Use this low frequency sequence geo- model to calibrate & drive G&G&P processing of trace data.
  - You spend a few weeks to integrate & double seismic geo- petro data. This should cut E&P cost & risk several %.

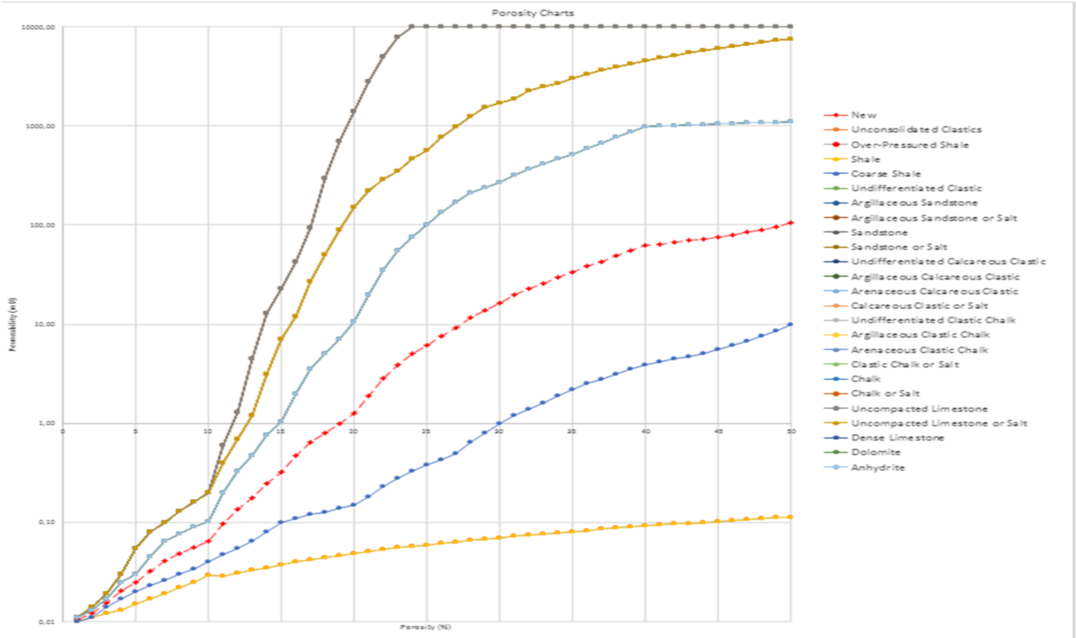
Velocity domain: poro-perms /lithology

- Picture of 30 lithologies in 15 groups, in brine & their porosity as a function of velocity.
- You tune this Dbase to fit your data.



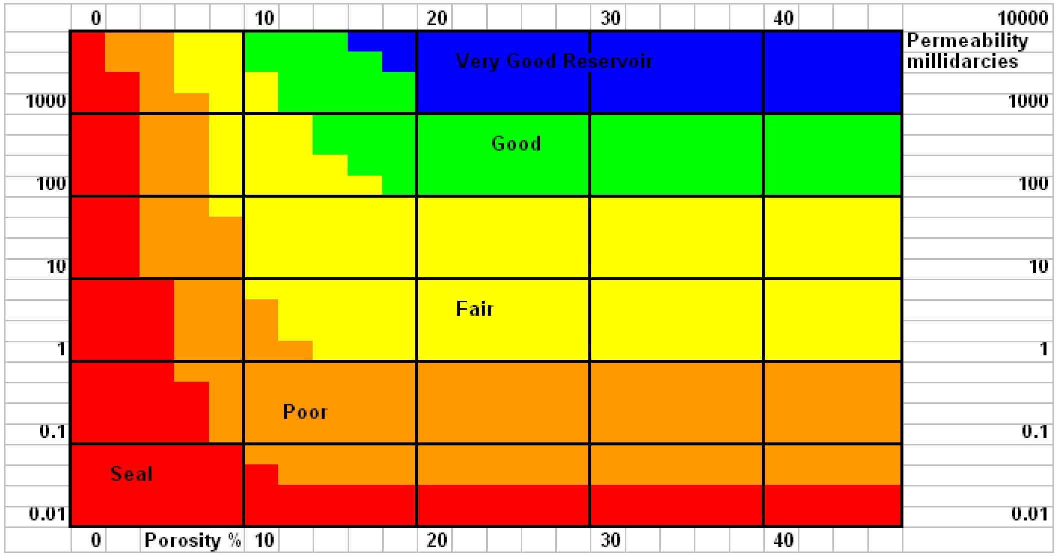
Velocity domain: poro-perms /lithology

- Picture of 24 lithologies in 6 groups, in brine, and their porosity % X-plotted against log scale permeability
- You tune this Dbase to fit your data



Velocity domain: poro-perms /lithology

- Picture of X-plot of porosity % and log permeability, coloured to show 5 groups guiding display of seal, reservoir, carrier bed properties.
- You tune this Dbase to fit your data, to best display seismic poro-perms.

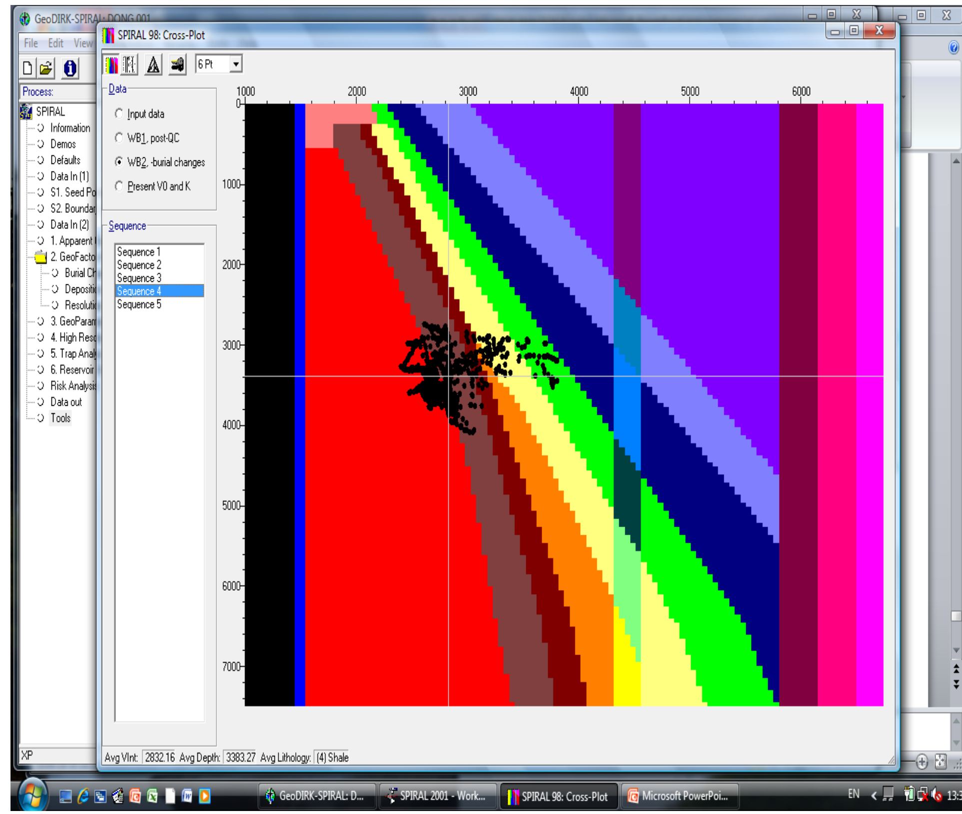


‘Normal compaction’, velocity, depth, lithologies. Vint = Vo + Kn

- Picture of Gardner’s type velocity horizontal/ depth vertical plot of key lithologies in brine

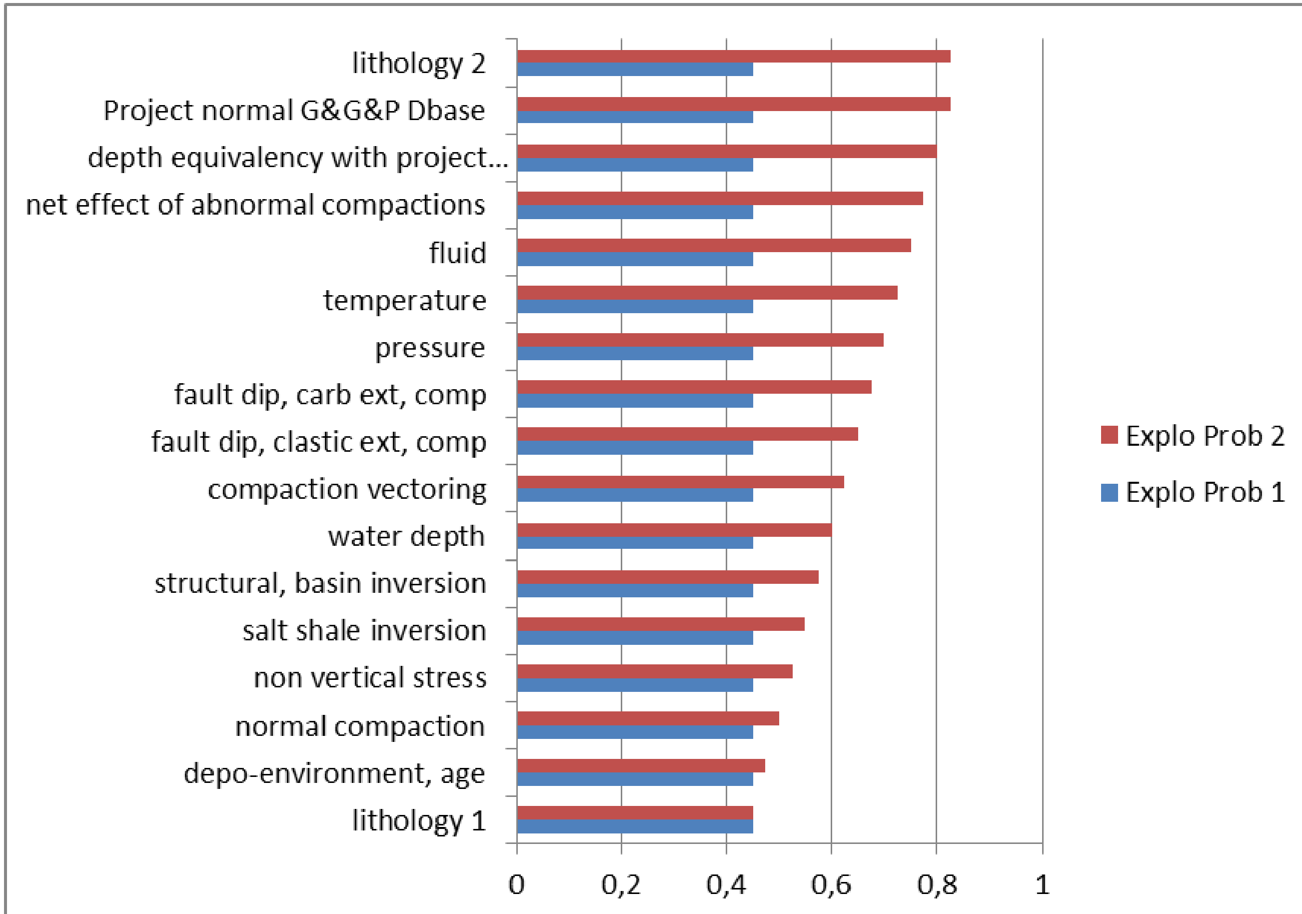
- Also various inter-bedded lithologies visible within one sequence rock volume sharing similar compaction.

- Red is o/p shale, brown shale, to yellow sand to blue carbonates etc.
- 4445 m/s could be salt.



Normalising rock volumes of similar compaction/ digenesis

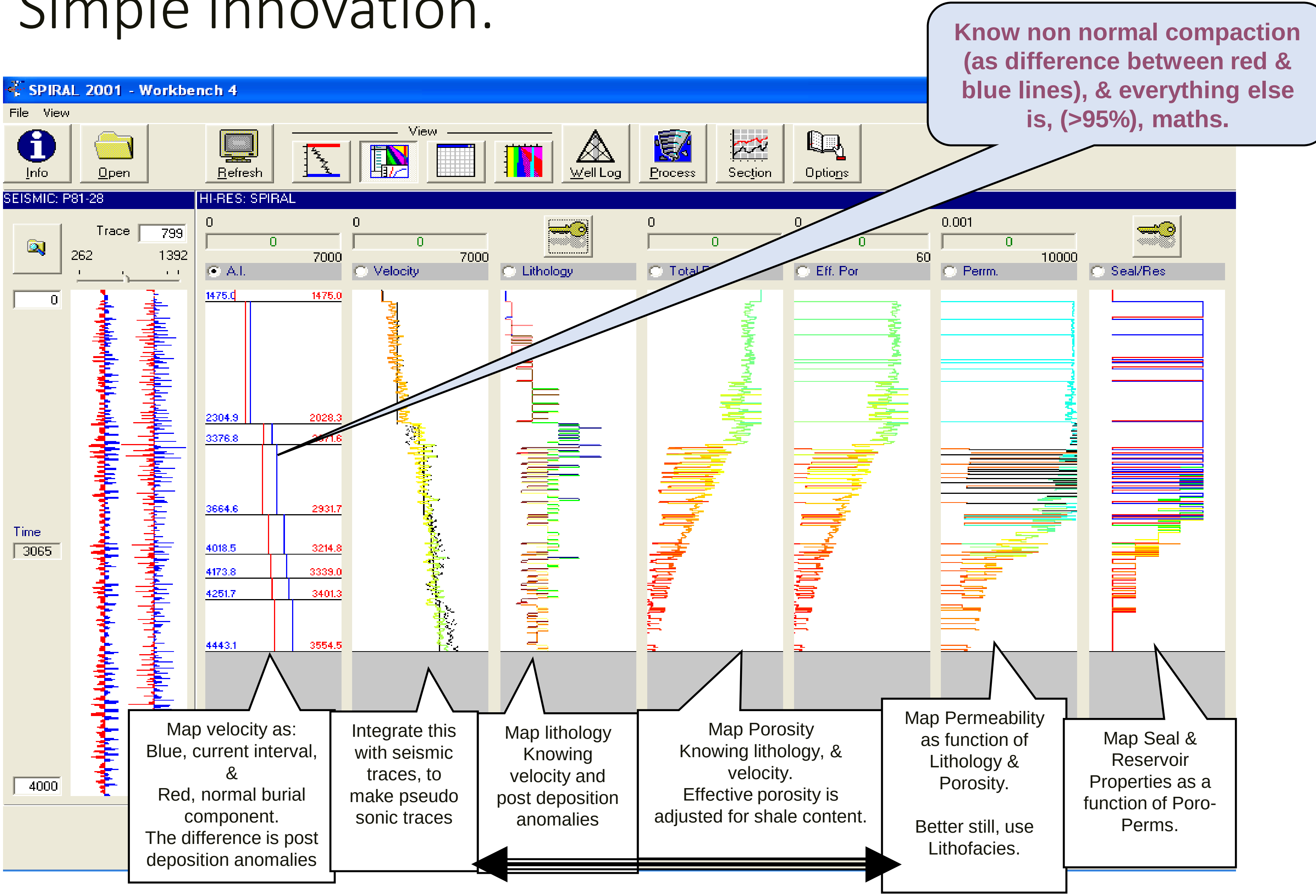
- Table of several geo-causes of non normal compaction with increasing depth, and programs providing QI of these risks.



X disciplinary integration seismic rock properties by sequence & sample depth normalisation

geophysics	geology	petrophysics	Normal DBase
Vint, Density, shapes		Porosity from lithology & Vint	Inter-relate
Vo	lithology	Permeability from lithology & porosity	Lithology
KNormal	Normal for lithology	Seal base from poro-perms	Velocity Vint
Vint of KAbnormal	Local abnormal burial changes	Trap GRV sub seal from poro-perms	Depth
		Trap NRV after fluid substitution (extra burial change)	Poro-perms

Simple innovation.

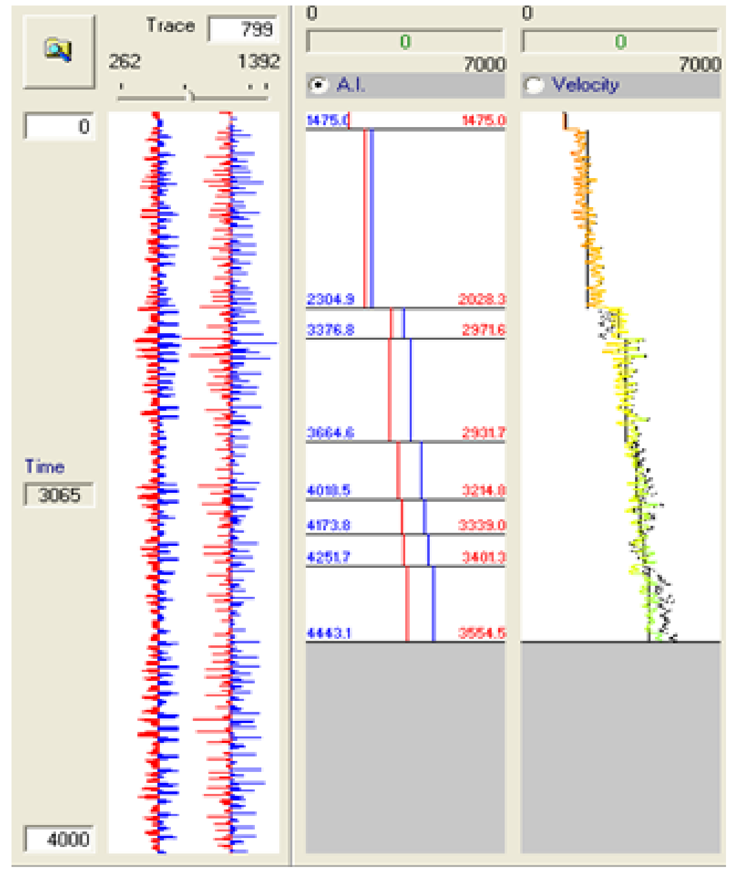


Porcupine, thanks to PAD & Spectrum

Seg-y seismic to velocity, for
a) depth conversion b) geo-petro normalisation

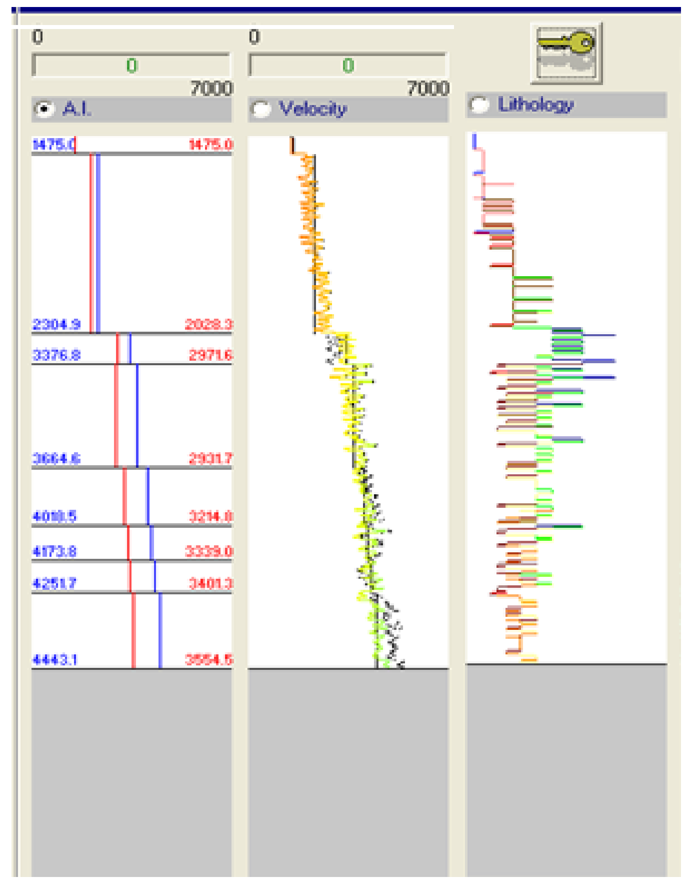
- Picture of trace samples integrated with low frequency sequence control, working AI changes from wavelet removal, then Vinterval.

- Picture of Vint shift for local KA abnormal compaction, based on average lithology mix and compaction rates.



Seismic to lithologies

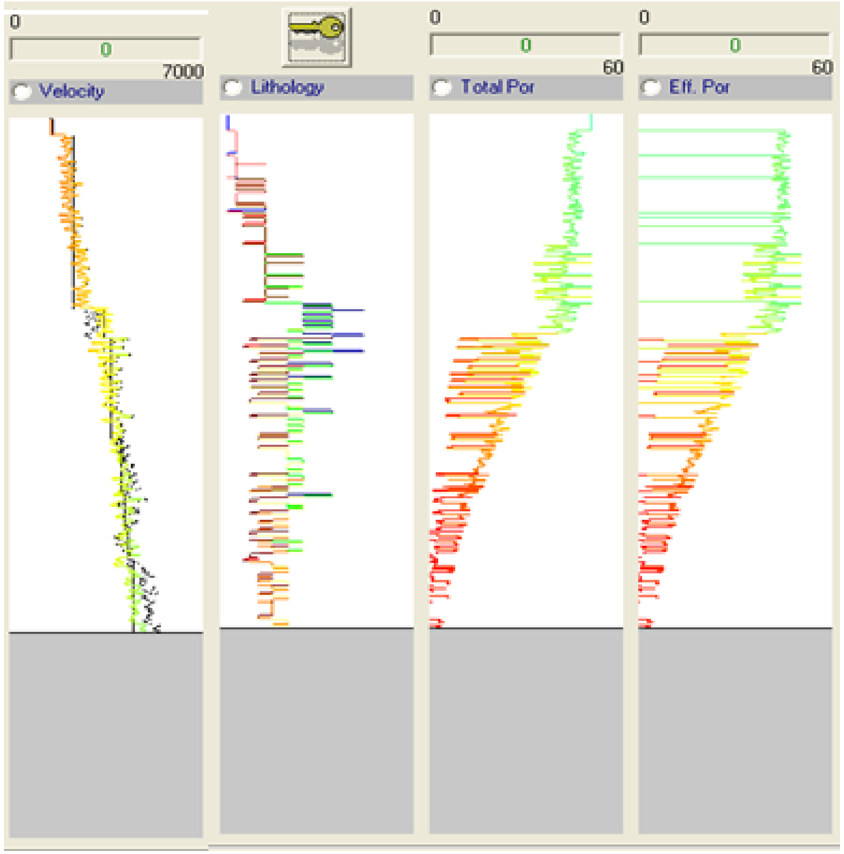
- Picture of trace conversion using Vo = VoN + KN +/- ΔD of Vint of KA
- Read lithology from sequence volume normalised to Gardner's type velocity/ depth plot



Velocity + lithology to porosity

- Picture of Geo-normalised Vint & Lithology traces, converted to porosity, total (then effective using lithology's shale content).

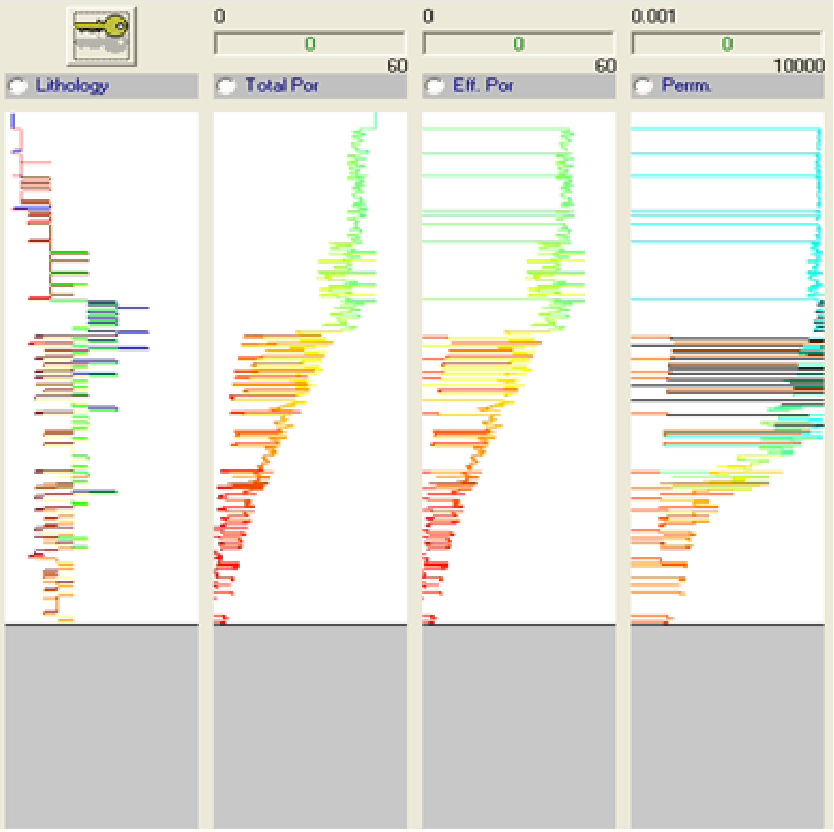
- Use depth shift / sequence to equilibrate with normalised property Dbase



Lithology, porosity to permeability

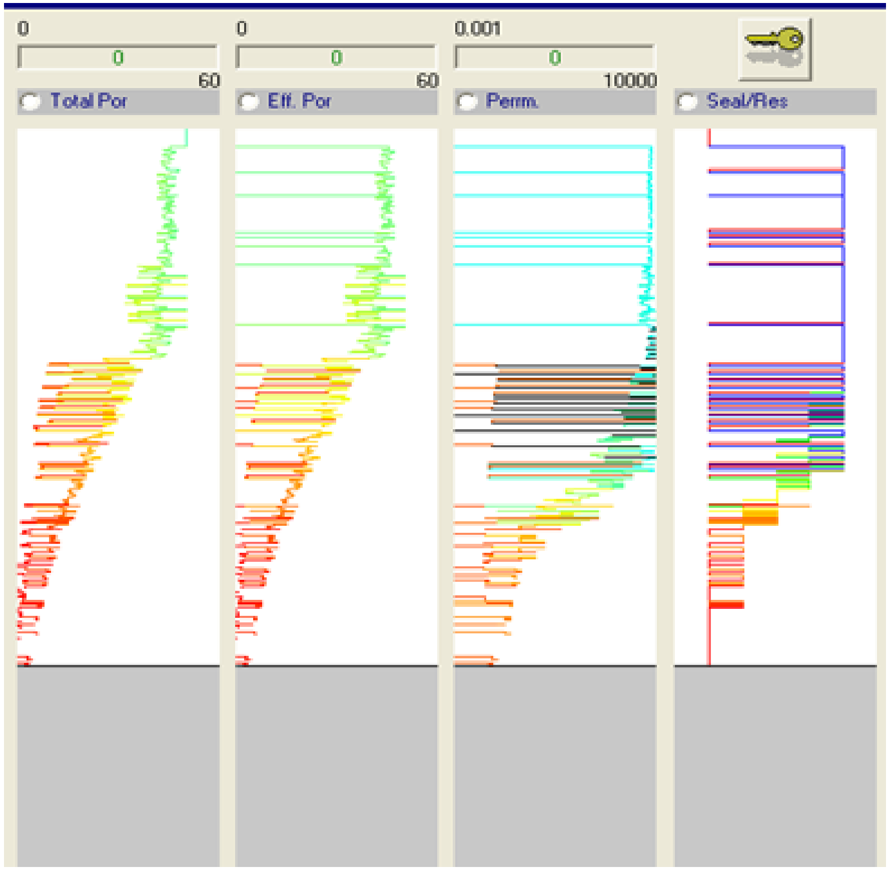
- Picture of a traces permeability, via X-plot / sample of trace lithologies & total porosities

- Use depth shift / sequence to equilibrate with normalised property Dbase



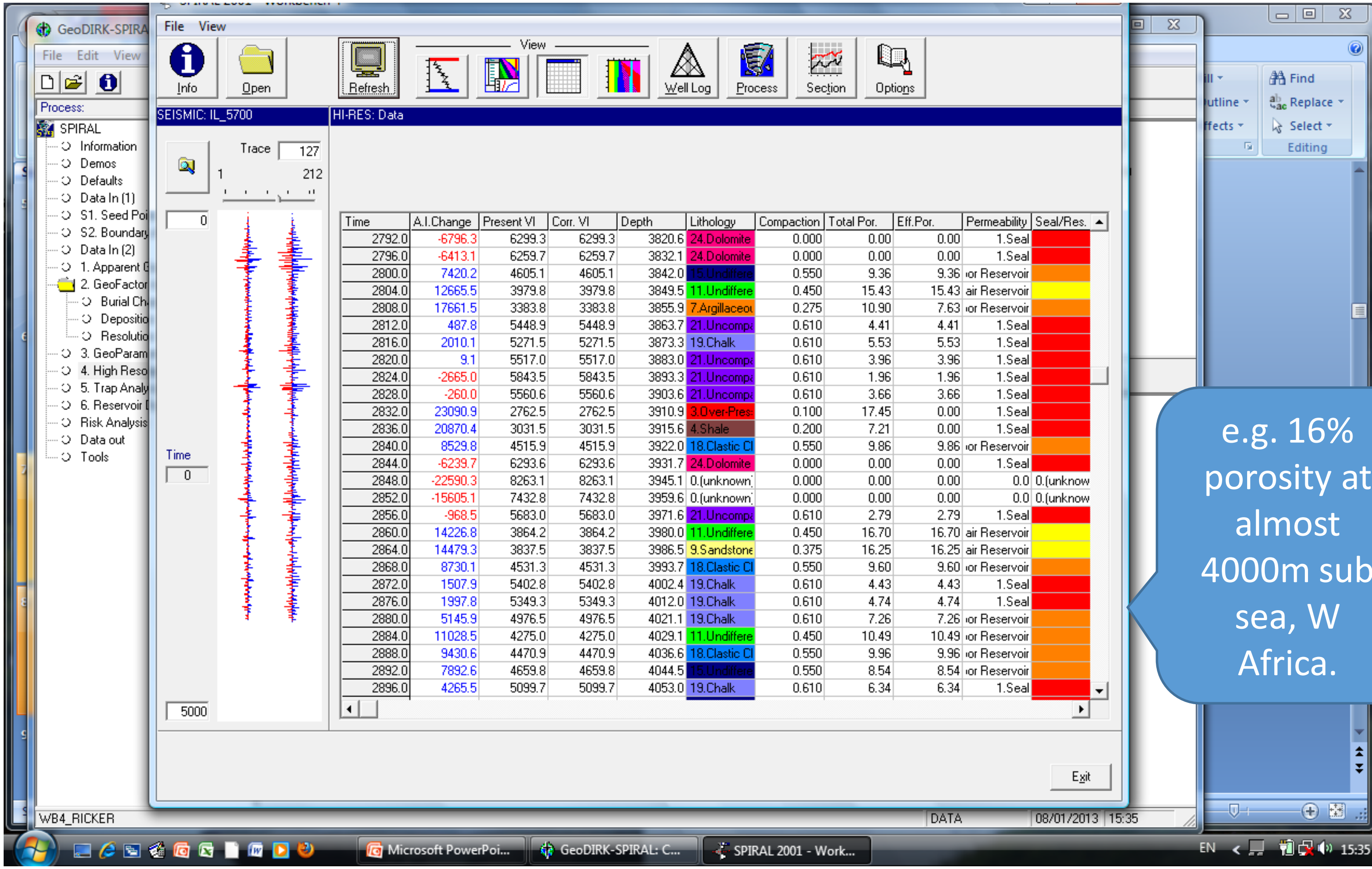
Poro-perms to seals & reservoirs

- Picture of seal – reservoir properties, from X-plot of trace sample poro-perms.



W/b 4 pseudo comp log

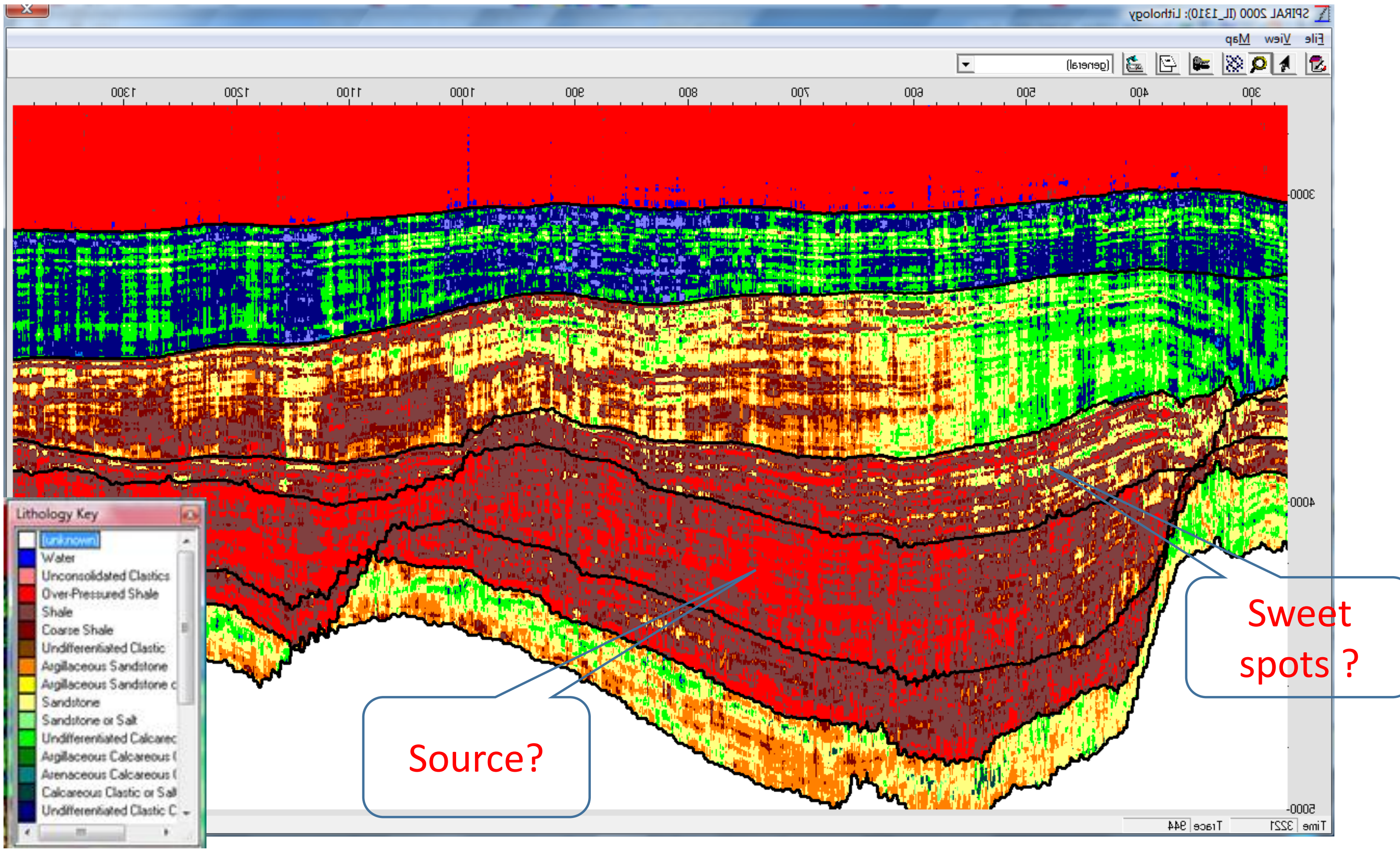
from every seismic trace, i.e. 80 x 80 per km2
(all of which are constrained by rules to make integrated G&G&P sense).



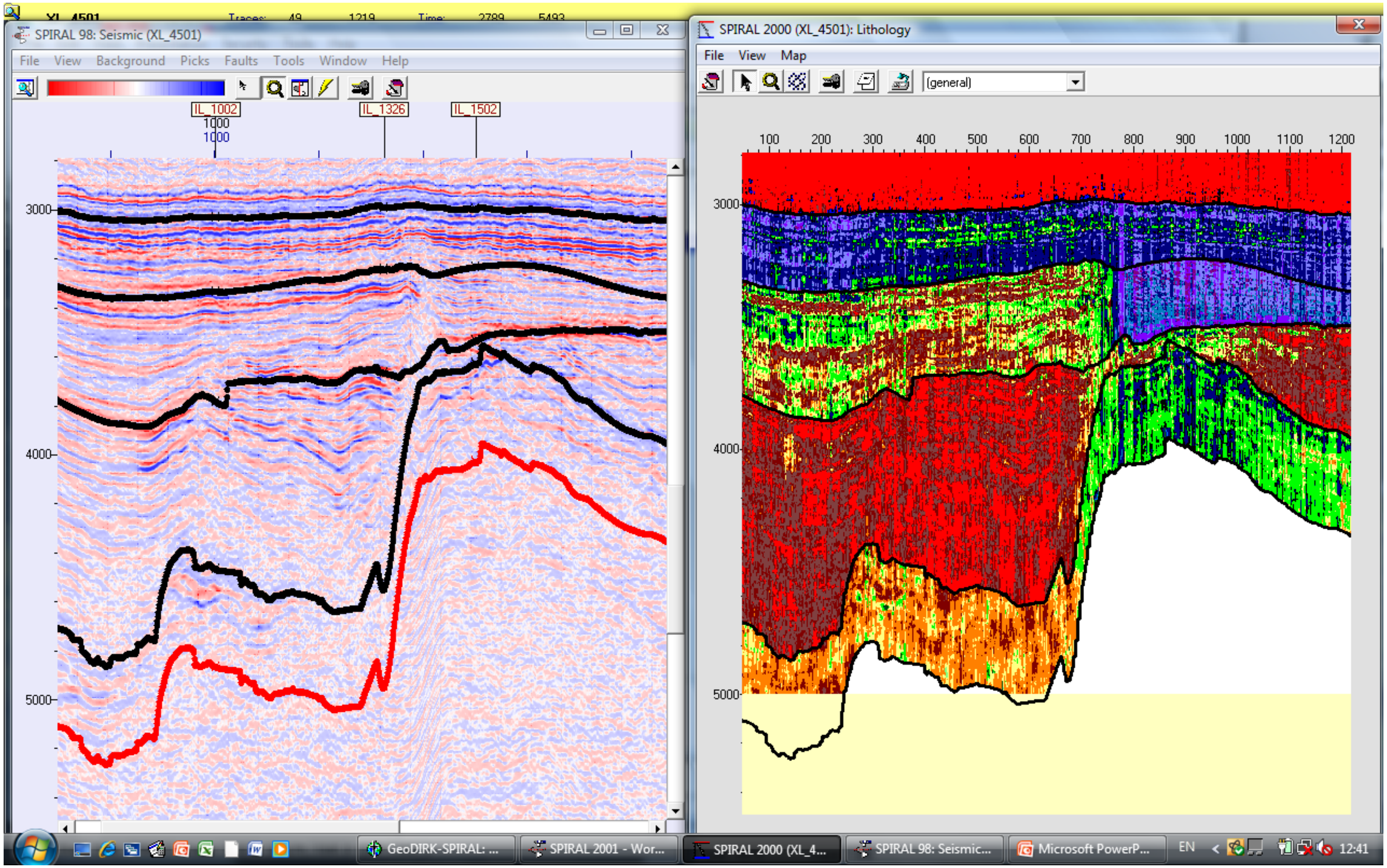
Time	A.I.Change	Present VI	Corr. VI	Depth	Lithology	Compaction	Total Por.	Eff.Por.	Permeability	Seal/Res.
2792.0	-6796.3	6299.3	6299.3	3820.6	24.Dolomite	0.000	0.00	0.00	1.Seal	
2796.0	-6413.1	6259.7	6259.7	3832.1	24.Dolomite	0.000	0.00	0.00	1.Seal	
2800.0	7420.2	4605.1	4605.1	3842.0	15.Undiffere	0.550	9.36	9.36	ıor Reservoir	
2804.0	12665.5	3979.8	3979.8	3849.5	11.Undiffere	0.450	15.43	15.43	air Reservoir	
2808.0	17661.5	3383.8	3383.8	3855.9	7.Argillaceoı	0.275	10.90	7.63	ıor Reservoir	
2812.0	487.8	5448.9	5448.9	3863.7	21.Uncompa	0.610	4.41	4.41	1.Seal	
2816.0	2010.1	5271.5	5271.5	3873.3	19.Chalk	0.610	5.53	5.53	1.Seal	
2820.0	9.1	5517.0	5517.0	3883.0	21.Uncompa	0.610	3.96	3.96	1.Seal	
2824.0	-2665.0	5843.5	5843.5	3893.3	21.Uncompa	0.610	1.96	1.96	1.Seal	
2828.0	-260.0	5560.6	5560.6	3903.6	21.Uncompa	0.610	3.66	3.66	1.Seal	
2832.0	23090.9	2762.5	2762.5	3910.9	3.Over-Pres	0.100	17.45	0.00	1.Seal	
2836.0	20870.4	3031.5	3031.5	3915.6	4.Shale	0.200	7.21	0.00	1.Seal	
2840.0	8529.8	4515.9	4515.9	3922.0	18.Clastic Cl	0.550	9.86	9.86	ıor Reservoir	
2844.0	-6239.7	6293.6	6293.6	3931.7	24.Dolomite	0.000	0.00	0.00	1.Seal	
2848.0	-22590.3	8263.1	8263.1	3945.1	0.(unknown)	0.000	0.00	0.00	0.0	0.(unknow
2852.0	-15605.1	7432.8	7432.8	3959.6	0.(unknown)	0.000	0.00	0.00	0.0	0.(unknow
2856.0	-968.5	5683.0	5683.0	3971.6	21.Uncompa	0.610	2.79	2.79	1.Seal	
2860.0	14226.8	3864.2	3864.2	3980.0	11.Undiffere	0.450	16.70	16.70	air Reservoir	
2864.0	14479.3	3837.5	3837.5	3986.5	9.Sandstone	0.375	16.25	16.25	air Reservoir	
2868.0	8730.1	4531.3	4531.3	3993.7	18.Clastic Cl	0.550	9.60	9.60	ıor Reservoir	
2872.0	1507.9	5402.8	5402.8	4002.4	19.Chalk	0.610	4.43	4.43	1.Seal	
2876.0	1997.8	5349.3	5349.3	4012.0	19.Chalk	0.610	4.74	4.74	1.Seal	
2880.0	5145.9	4976.5	4976.5	4021.1	19.Chalk	0.610	7.26	7.26	ıor Reservoir	
2884.0	11028.5	4275.0	4275.0	4029.1	11.Undiffere	0.450	10.49	10.49	ıor Reservoir	
2888.0	9430.6	4470.9	4470.9	4036.6	18.Clastic Cl	0.550	9.96	9.96	ıor Reservoir	
2892.0	7892.6	4659.8	4659.8	4044.5	15.Undiffere	0.550	8.54	8.54	ıor Reservoir	
2896.0	4265.5	5099.7	5099.7	4053.0	19.Chalk	0.610	6.34	6.34	1.Seal	

e.g. 16% porosity at almost 4000m sub sea, W Africa.

Run 1, Phase 1 velocities & sequences

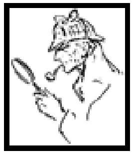


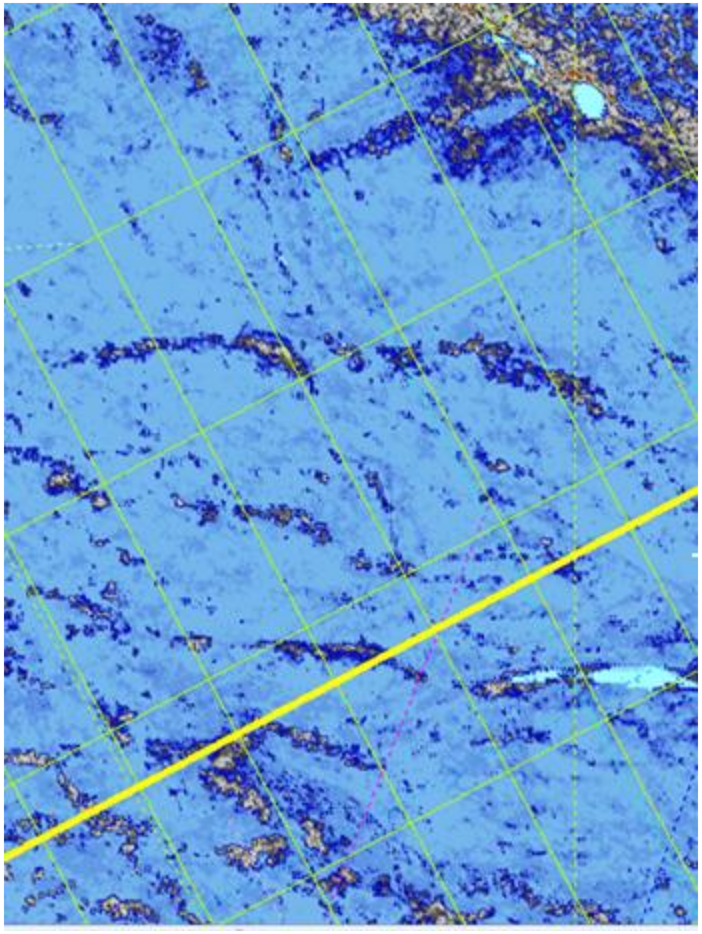
Processing sees (my) Chalk mis-pick



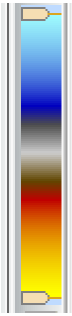
Mudstone seal above flattened top reservoir. About 4.5km depth

1.25 x 2.5 km



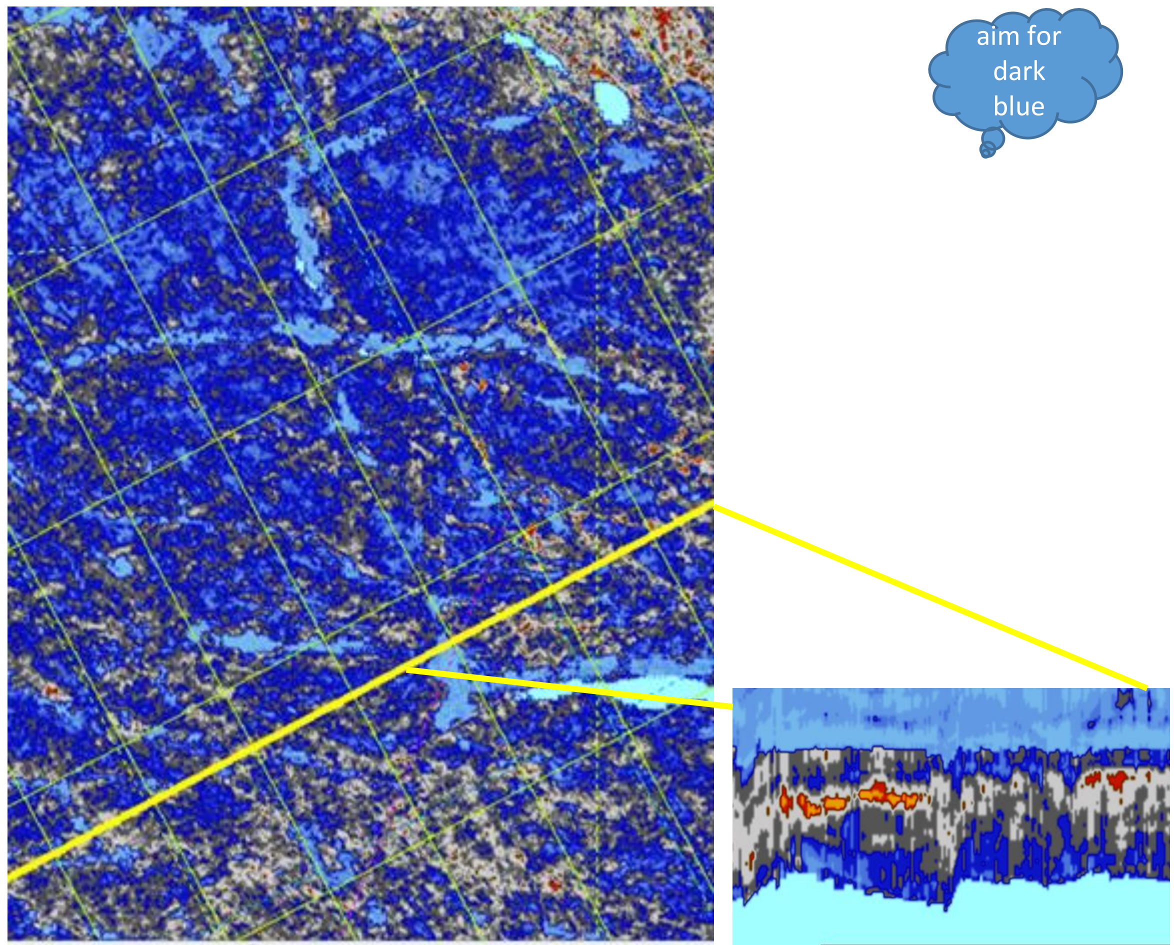


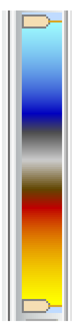
Viewed in Petrel with different colours/ lithology



16ms/ 33m below top reservoir

1.25
x 2.5
km

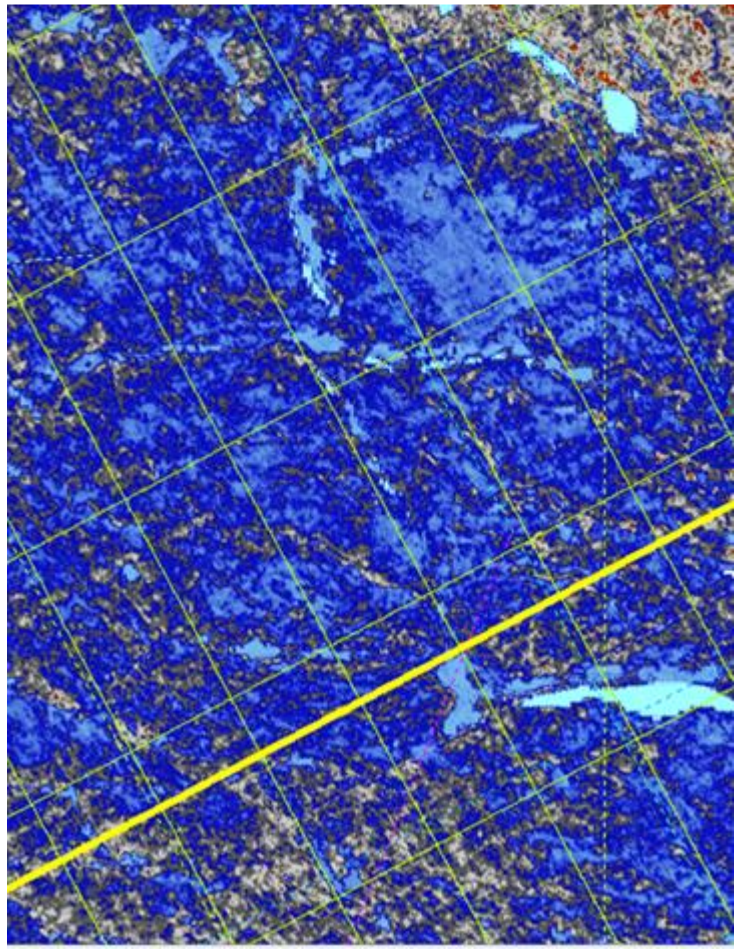




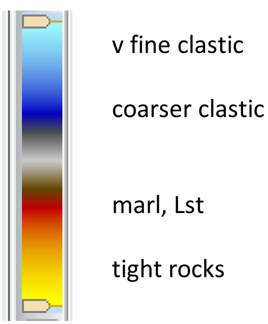
aim for
dark
blue

24ms/ 50m below top reservoir

1.25 x 2.5 km

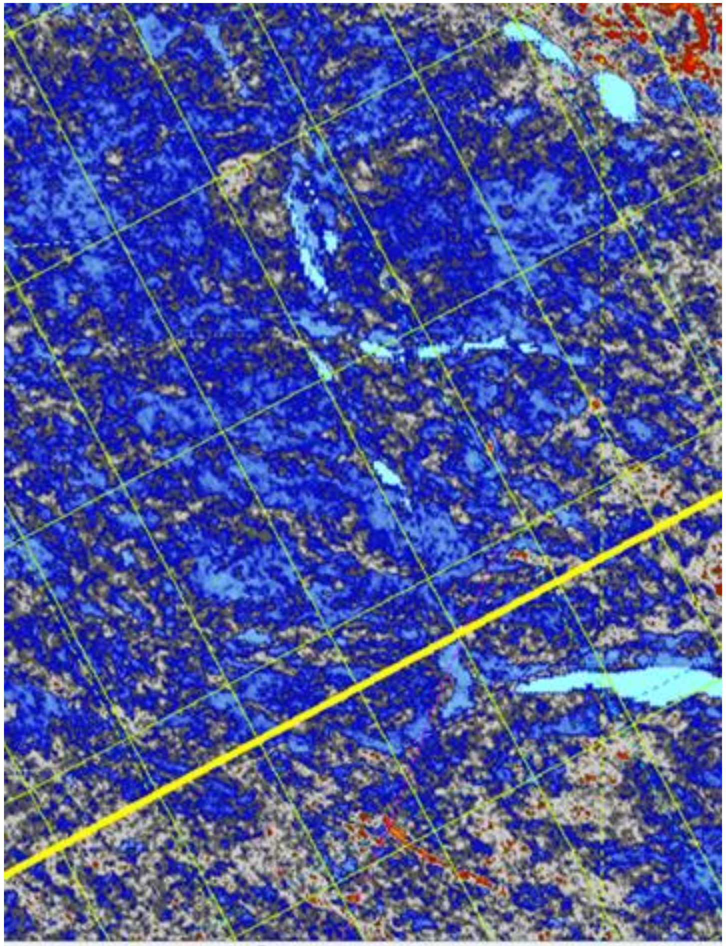


aim for dark blue



36ms/ 76m below top reservoir

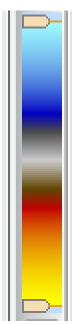
1.25 x 2.5 km



aim for dark blue

56 ms /118m, into volcano-clastics

1.25
x 2.5
km

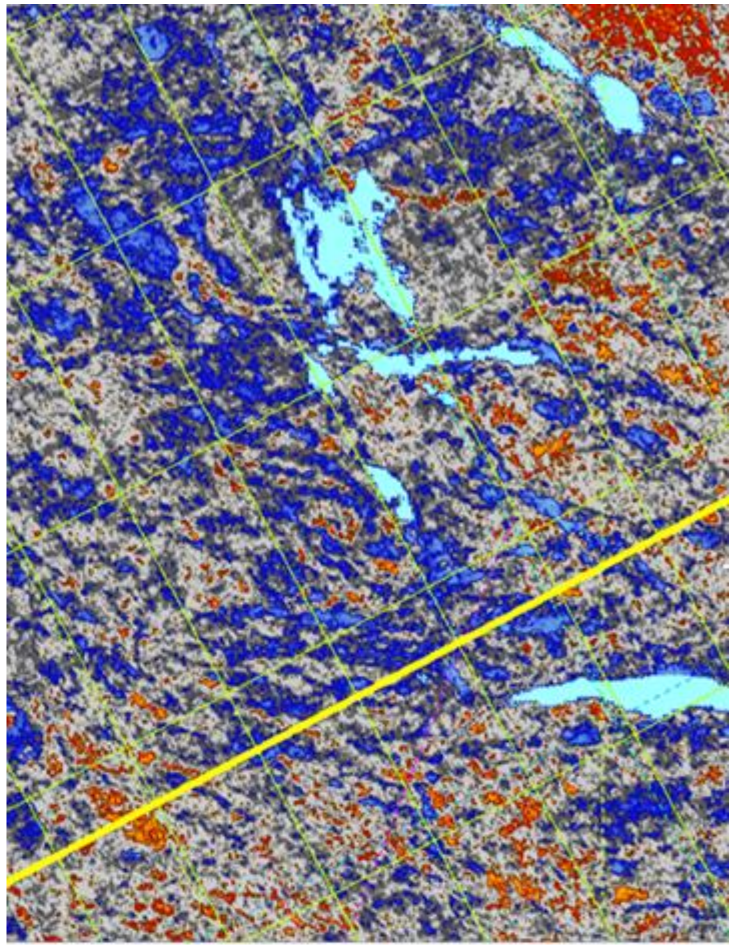


v fine clastic

coarser clastic

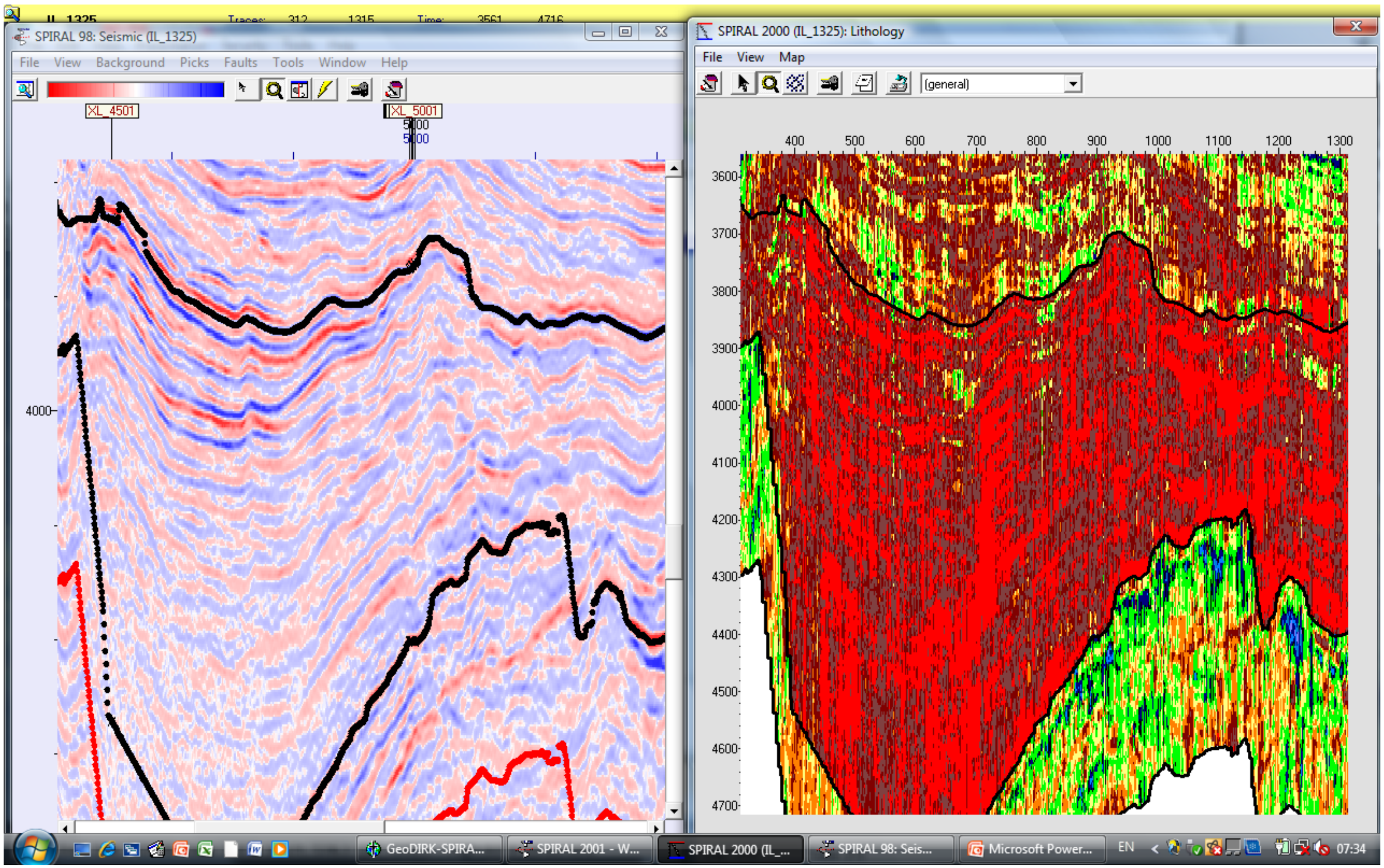
marl, Lst

tight rocks



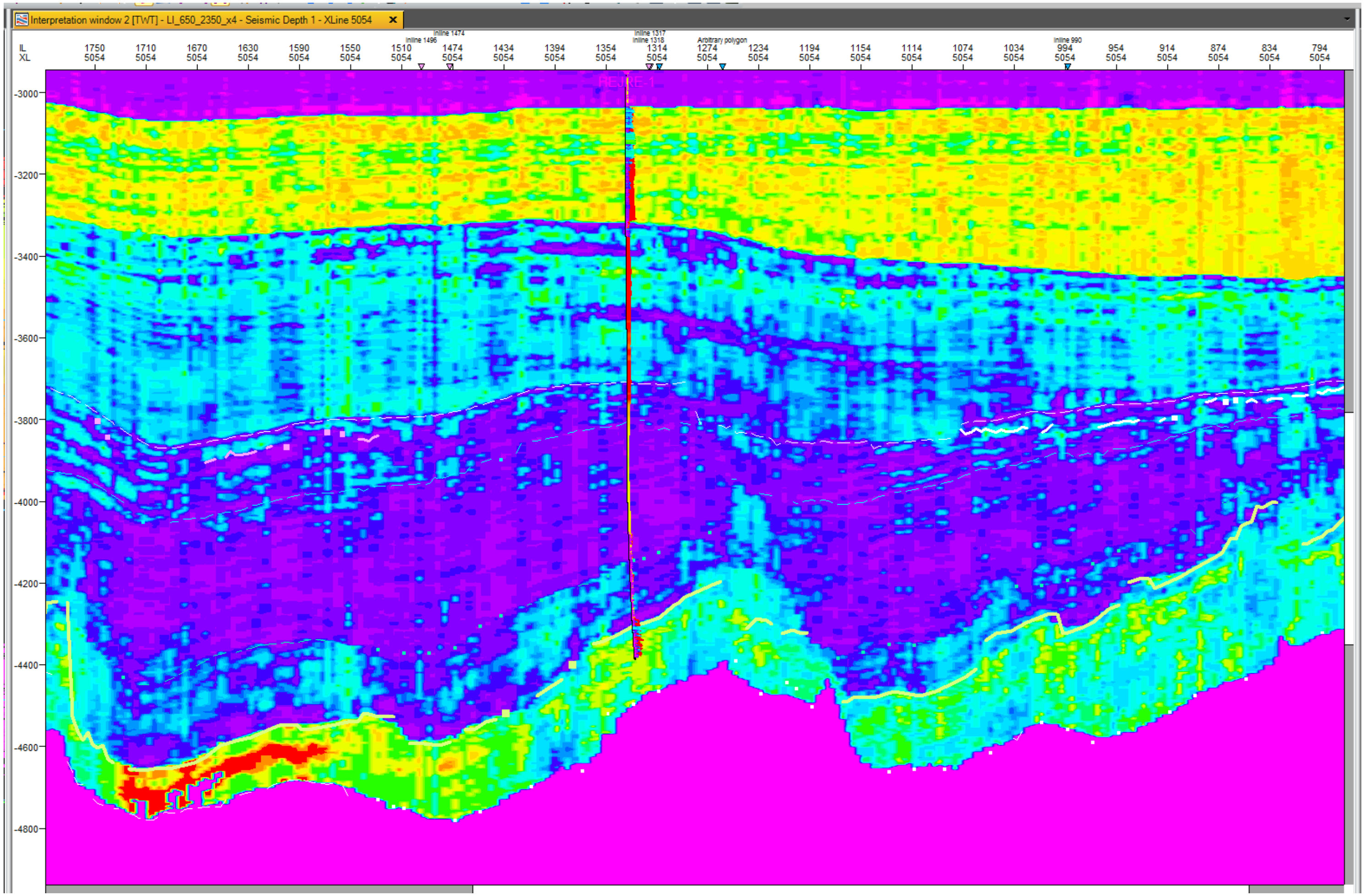
aim for
dark
blue

Variations in source/ seal + sweet spots



Back in Petrel, Well shows 2 zones of effective porosity.

Red (Permian?) Plots as 6000m/s, Anhydrite or igneous, grading laterally to volcano-clastic

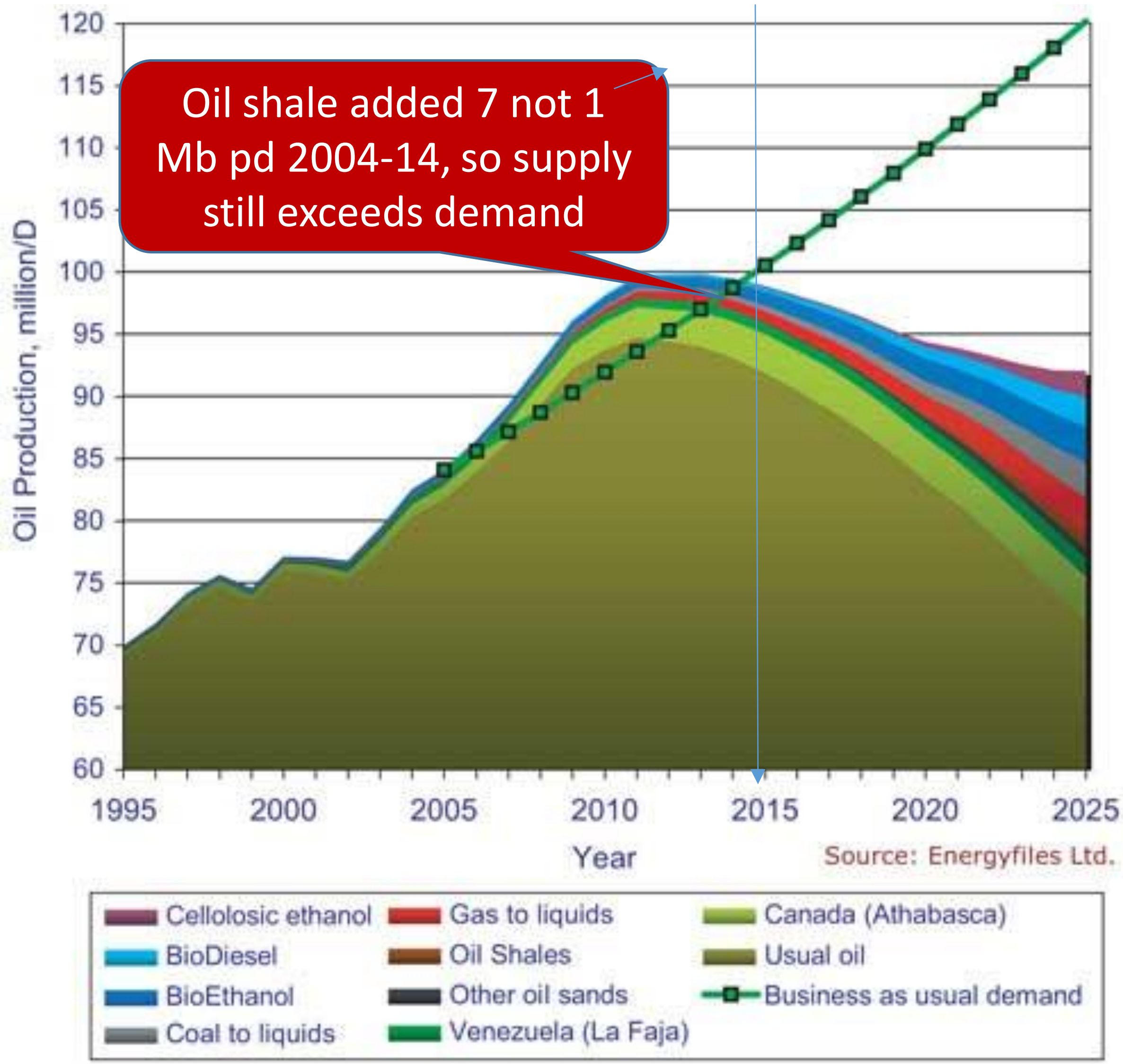


Last chance to increase acreage portfolio before ‘Peak Oil’.

(Paper at Society of Petroleum Engineers, R&D conference 04/07)

Estimate of future oil production showing the decline in conventional oil with shortfall ***(partly)*** **made up by unconventional hydrocarbons and synthetic sources.**
From paper ‘Technology for a Sustainable Tomorrow’
by Vik Rao, Senior VP and Chief Technology Officer, Halliburton.

Note 1: for 100 years, oil demand = population increase.
Note 2: >50% of usual oil comes from a few ‘ooo big, old fields, declining at 6% p.a. says IEA.



Drive geo-petro normalisation from your desk-top.

- Download project to GeoDirk processor
    - seg-y, processing velocities, sequence boundary files, well sequence property & geometry data.
- Confirm/ adjust processing parameters per processing stage online, QC output as input to next stage. Up load.
    - Sequence geometry model, assuming local normal burial
    - Sequence local normal geo-petro model
    - Sequence geometry/ geo-petro model, adjusted for localised burial- digenesis controls. Define ΔD to equilibrate to normal.
    - Trace sample / integrated with sequence controls
        - AI, Vint, Vo + KN +/- Vint of KA, lithology, poro-perms etc
    - Seal base geometry, trap GRV, rework fluids, properties,
        - Per Trap, GRV, NRV, rock geology & properties for simulation.

Fit with other seismic post, (pre) stack processing, inversion, EM etc

- The main risk associated with QI quantitative interpretation processing of seismic to poro-perms, fluids etc. is potential for spatial changes in lithology, relative to model used.
- Generation of a more detailed inter-well geologic model, plus conversion to lithology, poro-perms etc.,
  - Focuses other QI processing to volumes of E&P potential
  - Provides input to the model used in required QI processing.
- EM delivers evidence of oil, gas presence,
  - Location is approximate, and permeability needs to be known.

Generating most probable geo or petro model for simulation

- Take a bell curve from many simulations of possible distributions of geo, petro data from well data + seismic sequence shapes.
- Doubling inter-well geo, petro data by integrated seismic normalisation will almost certainly reshape, reposition bell curve derived as above.
  - Objective, robust, easy to understand & QC way to do this is by shifting up & down, best fit of ΔDepth used in cellular processing

The 80-20 rule & how you evolve step change rules & tools

- 20% of the work is done, establishing the rules (IP) & tools (look & feel of IT©). The framework works.
  - Accuracy of output tends to be around 80%, at a few man weeks processing per project per month.

- 80% of extra work should be done to enhance the rules and tools of E&P REIT geo-normalisation
  - Then you can increase current levels of accuracy and rate of worked deliverables, building your group edge.

Serving geo- petro normalisation

- You generate quality seismic plus sequence boundary time, velocity, depth, and well datasets.
- At 12.5m3, 3D seismic gives good velocity. Know geology in numbers summing lithology and compaction/ digenesis, and we should sensibly compute poro-perms. Errors mapping cellular lithology, upon which poro-perm prediction is risk contingent, is E&P's key cause of inefficiency.
- Geo-normalisation enables expert staff to drive rule based expert systems to integrate geophysics with geology, and petro-physics via processing, so oil company experts can work together more productively and focus their experience on E&P play, prospect and field analysis.
- DON'T focus expenditure on quantifying project geology and associated petro physical, play and field parameters, from local well data alone, as if this describes potential for cellular properties.
- DO focus on increasing objectivity and efficiency of use of quantitative interpretation, seismic +/- well data, to geo- petro normalise local data relative to an in-house QC'd generic standard.
- Work G&G more efficiently, and make E&P drilling & facility engineering cost more efficient, by controlling inter-well poro-perm models, via sensible seismic cellular geological modelling.
- Email info@geodirk.com to access G&G support and use of expert systems, to normalise inter-well seismic data to sensibly fit well based geo and petro models in an optimised, repeatable uniform manner, so you can work up more, lower cost and risk, E&P opportunities.

Geological normalisation of seismic.

*In theory, it doubles G&G productivity, to cut E&P cost & risk by 15% *:*
Practice, in >20 projects (all geologic systems), tends to prove theoretical potential.

- Prime cause of E&P inefficiency is wrong inter-well forecast of poro-perms, largely risk contingent upon knowing geology as causes spatial property change.
- G&G defines geology via well and sequence shape models, then simulates potentially compounded variations caused by (some 15 factorial) changes in sedimentation, lithofacies and /or structural geology, compaction, digenesis, fluids etc.
- To significantly enhance E&P success requires processing of seismic into better geologic, then poro-perm, and fluid models.
- Seismic now provides relatively accurate pseudo sonic log, time, velocity, depth data per 12.5m trace, at <12.5m vertical. P & S velocity data can be gathered pre stack. Seismic provides excellent seismic stratigraphic shapes, potentially enabling quantitative interpretation (QI) to better define geology of deposition and burial changes.
- Where inter-well cells compact normally relative to well data, conversion to inter-bedded lithologies and their poro-perms should be low risk. Therefore, normalisation, per seismic volume having similar burial compaction controls, allows equilibration by depth shift, with well based ‘normal’ depth compaction. This allows conversion of seismic to geo and petro information that is risk dependent primarily on quantification of burial depth equilibration shift.
- Expert geo-detectives need to re-focus seismic +/- well data to filter presence / absence of such geo-causes of property change, relative to burial-change ‘norm’ then generate a normalised, single most probable geo-petro model. QI filters cellular data to quantify separate and net effects of causes of burial changes. Then, cellular seismic numbers = cellular geologic numbers of deposition and burial changes = cellular petro-physical numbers, in one, most probable, harmonious, multidisciplinary integration, containing presence / absence of geo-risks.
- Integrating, analysing, visualising and correctly interpreting extra multi-disciplinary measurements goes beyond desktop applications available today. So, we beta tested, in > 30 data sets each >600km3, ‘apps’ to process cellular evidence crucial for geo-detection, for current workstations.

(* Independent UK State commissioned evaluations of KA’s patents)