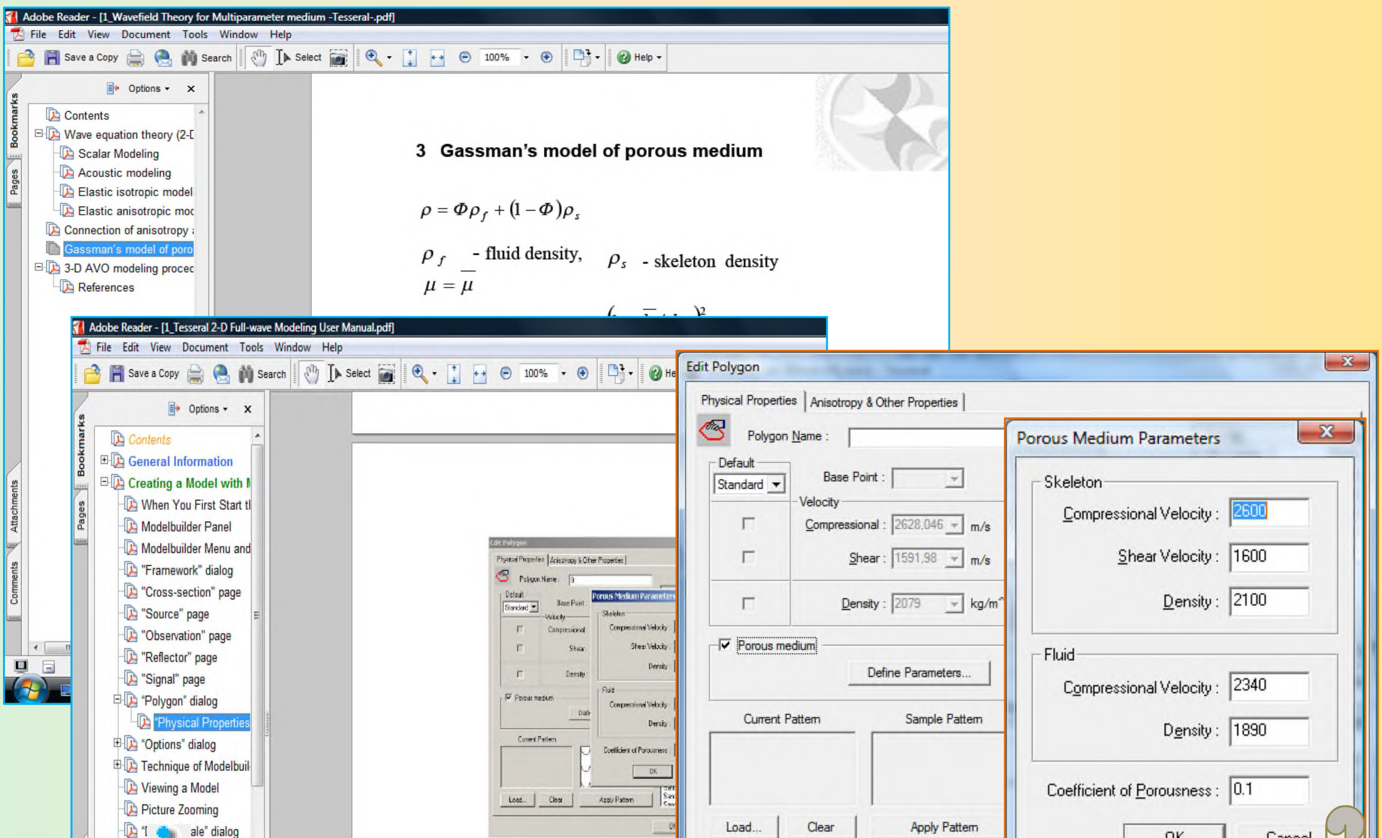
Seismic MODELING using MEDIUM MICRO-MODEL PROPERTIES for porous fluid-saturated (the Gassman formulae of the porous model), anisotropic, fractured, absorbing Media



Inline Help provides user with different kinds of information relating to these topic s

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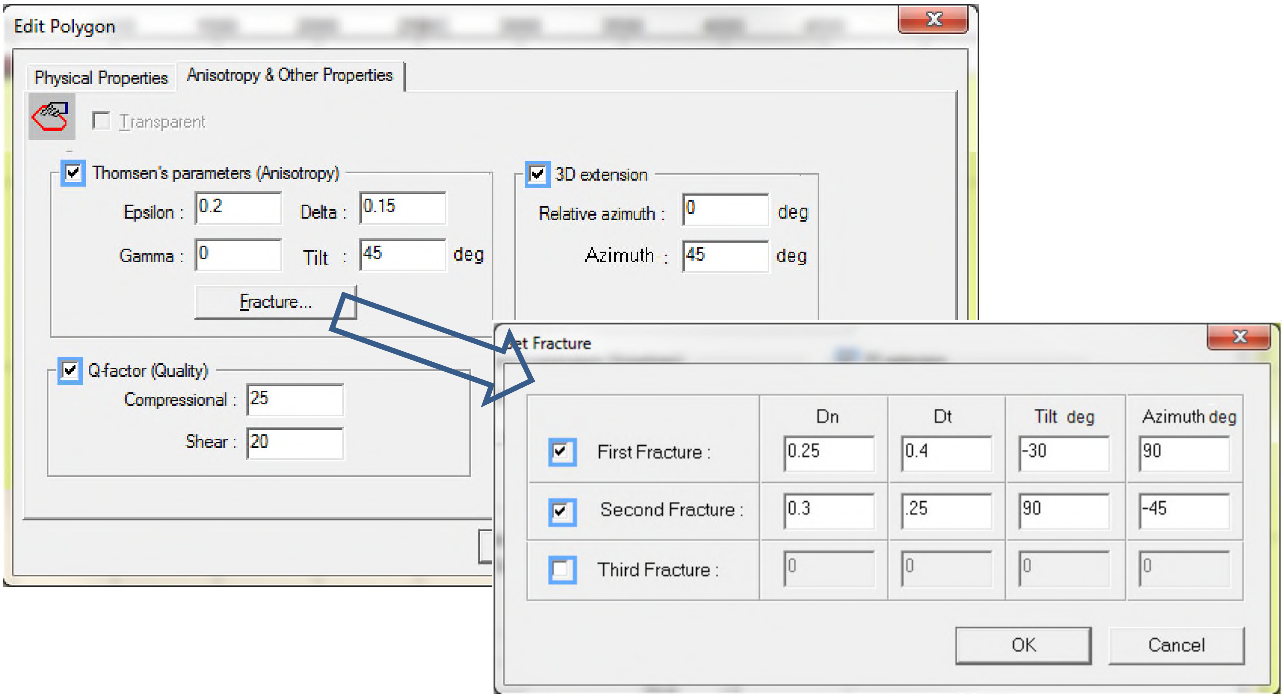
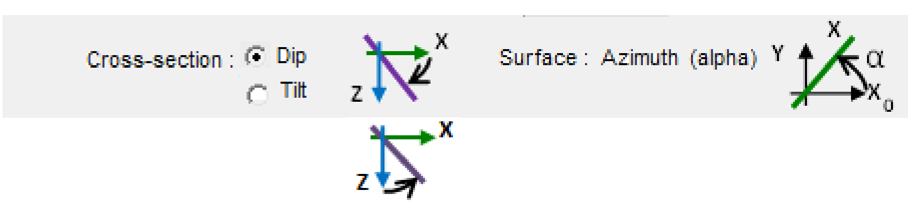
May-12

❖ Modeling Anisotropy and different fracturing systems



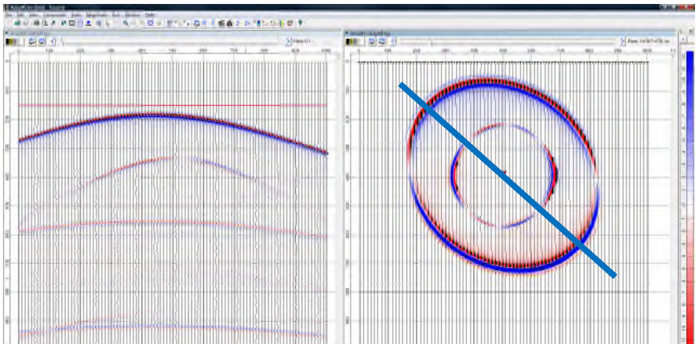
Package models the wave field propagating within transversally isotropic and ortho-rhombically symmetrical media along any anisotropy axis

Options for 2D and 3D setting of angles:

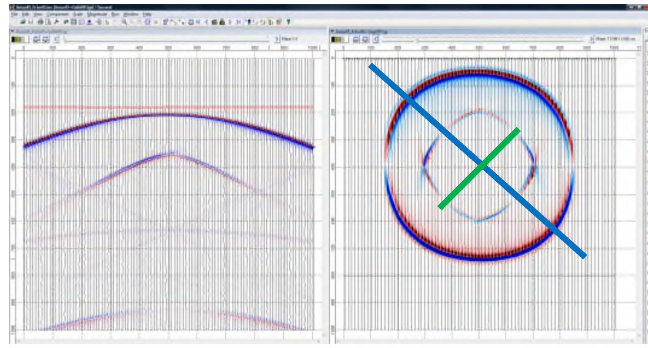


Anisotropy modeling mode allows entering Thompsen's parameters: Epsilon, Delta, Gamma (between -0.2 and 0.2) tilt angle Phi (between -90^0 and 90^0) and azimuth (between -180^0 and 180^0, 3D case extension).
Those values can be entered for any polygons of the model (not necessarily for all)

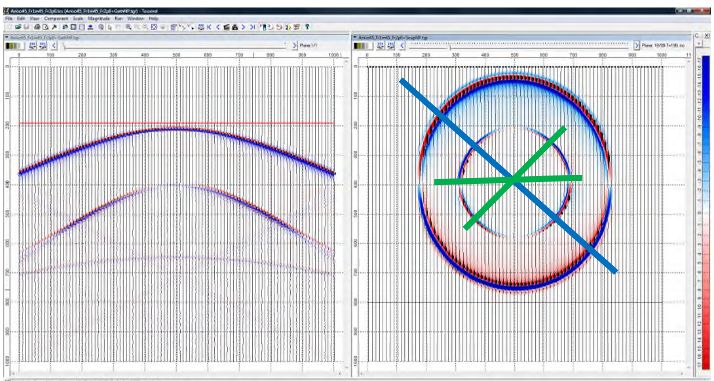
❖ Modeling Anisotropy and different fracturing systems



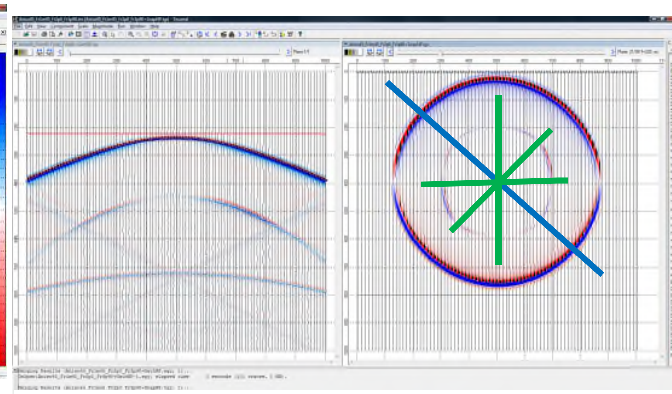
Model "Aniso45" (45 deg dipping of anisotropy axis)



+ #1 fracturing system -45 deg dipping



+ #2 fracturing system 0 deg dipping



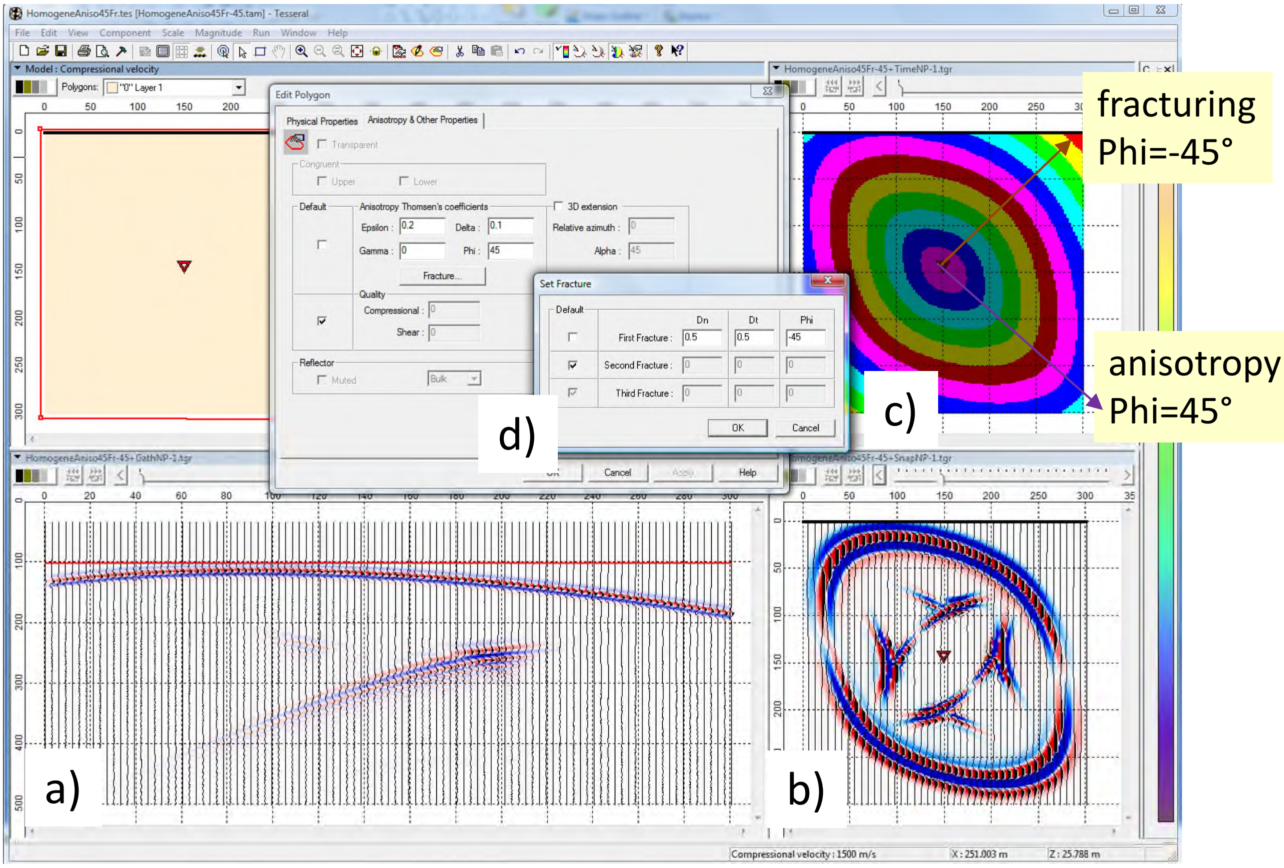
+ #3 fracturing system 90 deg dipping

Each layer usually represents homogeneous anisotropic medium.

Generally, anisotropy is monoclinal with symmetry axis coinciding with the plane of computations.

For fracturing systems in the transversally isotropic medium (TI), the symmetry axis of TI-medium or the normal to planes of fracturing are assumed to be within the computation plane (2D case) or have particular azimuth (3D case).

❖ Modeling Anisotropy and different fracturing systems

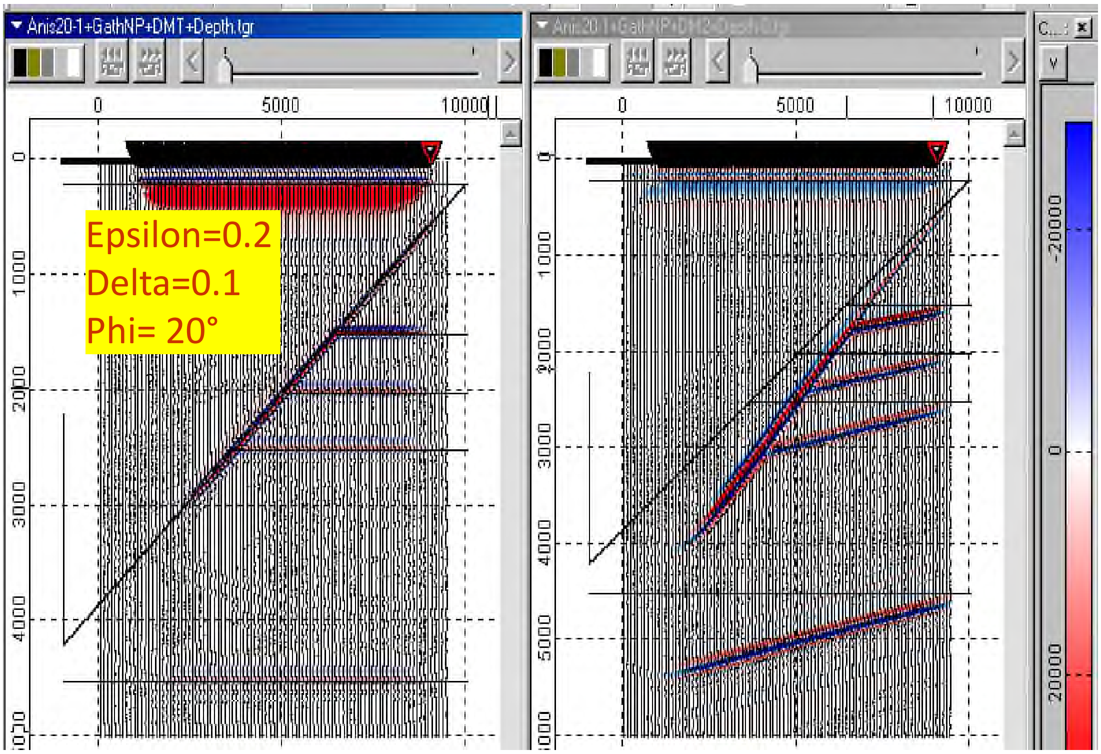


Shotgather (a), Snapshot (b) and Time field (c) of first arrivals in anisotropic fractured medium for model with inclined anisotropy and fracturing axes. It can be seen that strong anisotropy and fracturing (d) can considerably distort propagating S-wave field (b).

For each fracturing system, users then enter the parameters Δ_n and Δ_t (no units), tilt angle of fracture plane (ϕ) and azimuth (α in 3D modeling case) with respect to the vertical direction.

In *Tesseral* package, users can add up to 3 fracturing systems into the background isotropic or TI-medium with tilted symmetry axis.

❖ Modeling Anisotropy and different fracturing systems



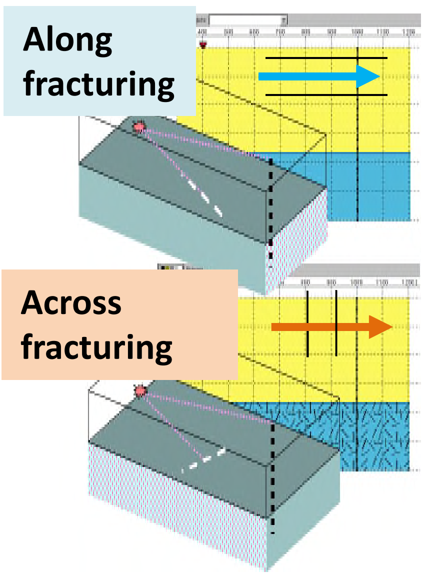
a b

Comparison of migrated cross-sections with source model (shown on background); when anisotropy is taken into account (a) and when anisotropy is not taken into account (b).

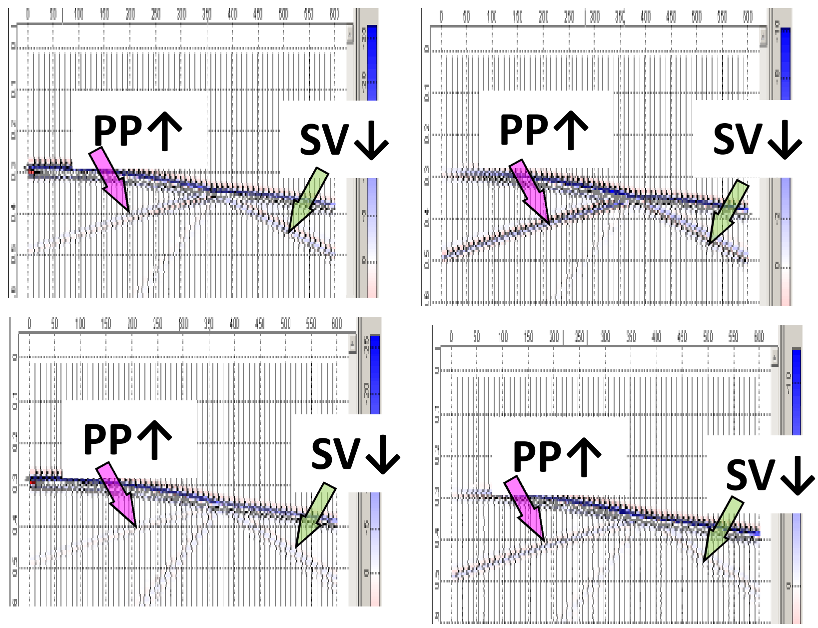
Not taking into account of the medium anisotropy properties can lead to erroneous interpretation of processing results and following decision making

❖ Modeling Anisotropy and different fracturing systems

Example of **fracturing** modeling for VSP



Z-component **X-component**



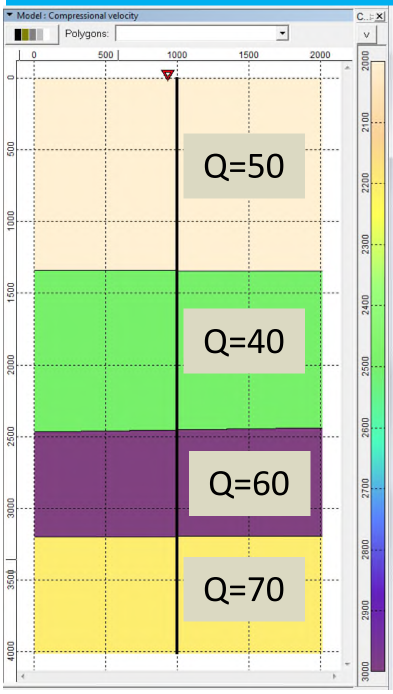
On VSP shotgathers P-waves are shown with red arrows, converted PS-waves – green arrows.

PP↑ Reflected P-wave

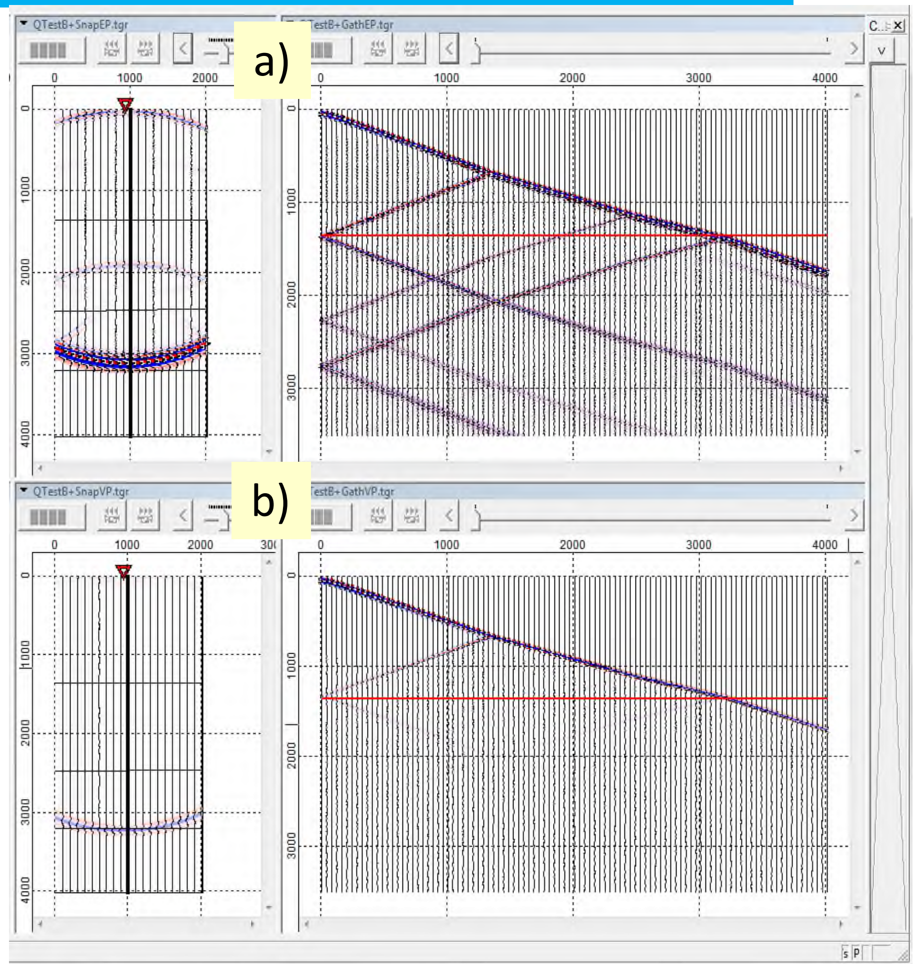
SV↓ Transmitted converted S-wave

Modeling allows to clearly identify capabilities and main factors for fracture detection.

❖ Modeling Q-factor Absorption



Source model with absorption ***Q-factor values close to the average ones for sediment rocks***



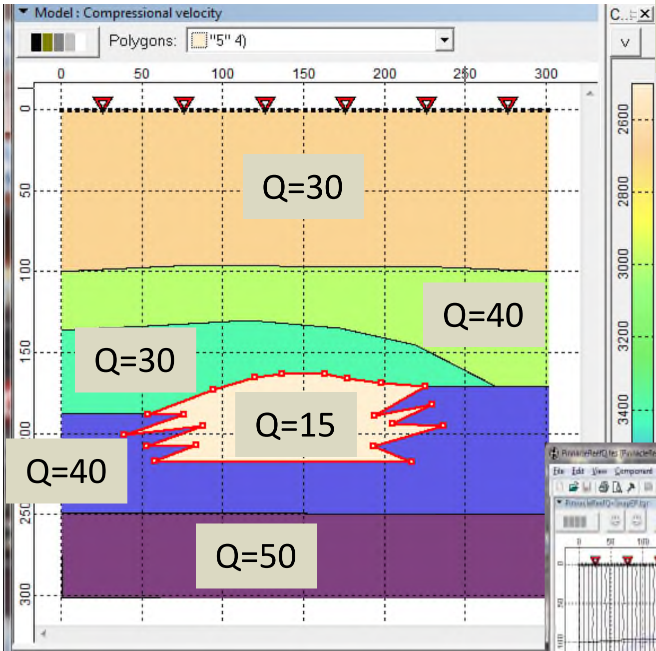
Left – snapshot of wave field, ***Right*** – shotgather (Vz-component);

a) Elastic Modeling (no absorption, linear wave approximation);

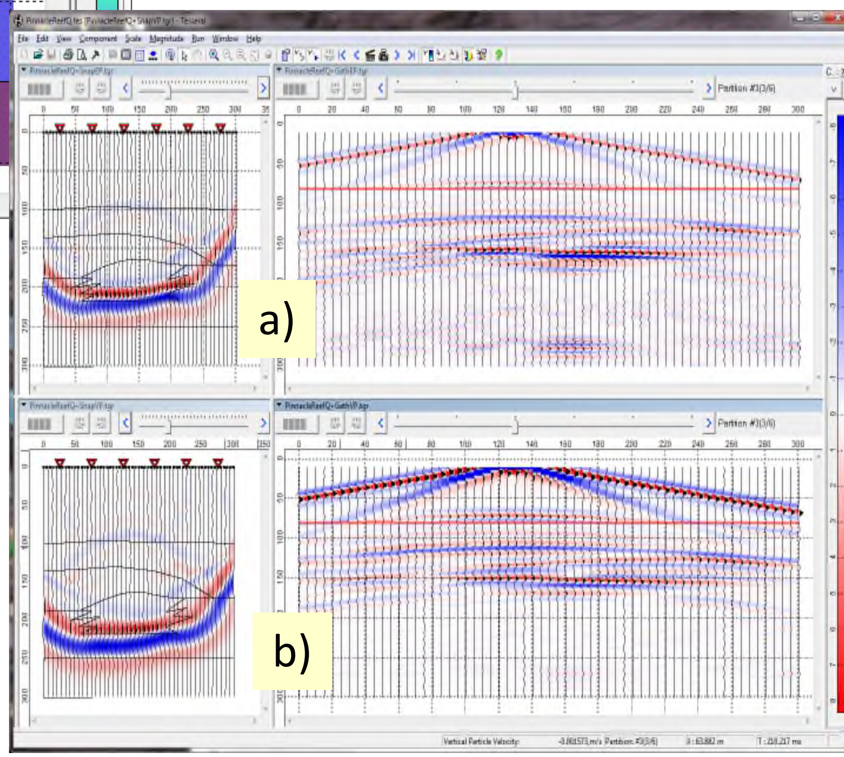
b) Visco-elastic Modeling (absorption, non-linear wave approximation); Reflected wave amplitudes are significantly attenuated in comparison with case a).

In general case, quality factor Q depends on the frequency content of the seismic wave propagating in visco-elastic medium, which is simulated using corresponding visco-elastic wave equation approximation. Quality factor Q affect the velocity dispersion (wave is scattered or distorted as function of frequency).

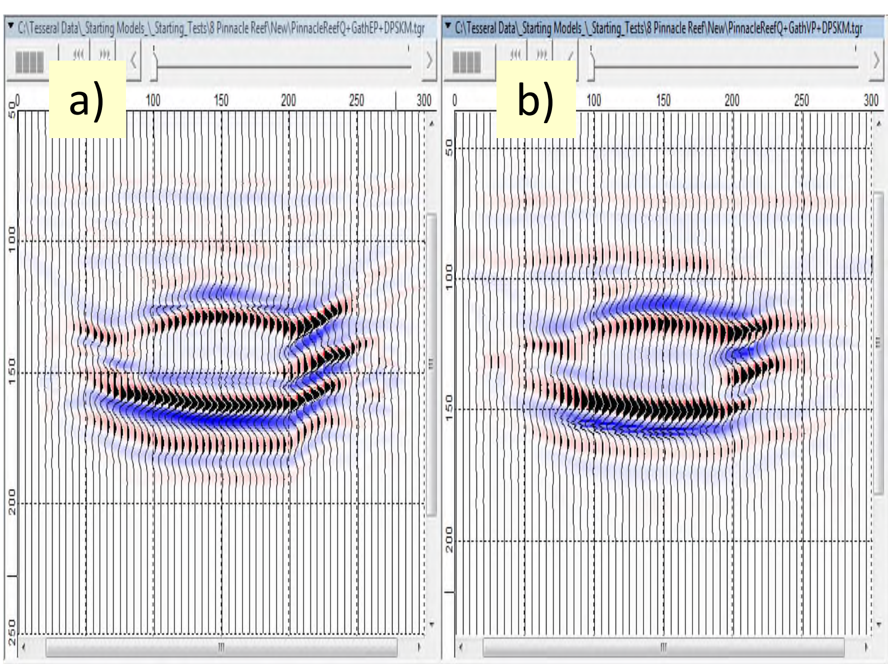
❖ Modeling Q-factor Absorption



"Pinnacle Reef" model (300x300m)
Source Peak Frequency =100Hz
Q-factor values are *close to the average ones for shallow sediment rocks, except Reef body with Q=15*



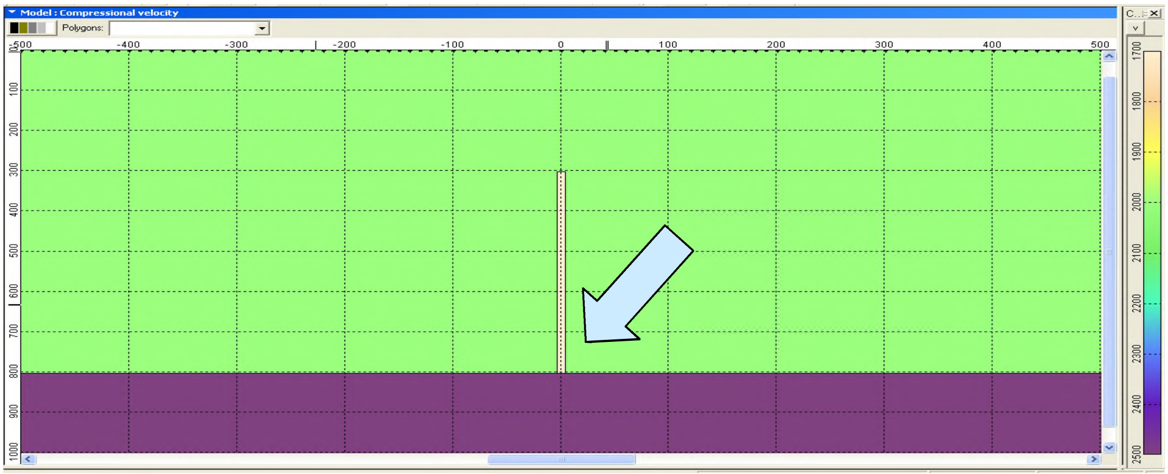
Left – snapshot of wave field, ***Right*** – shotgather (Vz-component);
a) Elastic Modeling (no absorption, linear wave approximation);
b) Visco-elastic Modeling (absorption, non-linear wave approximation);
There can be seen ***significant difference between a) and b) in relative amplitudes*** of different correlated events.



Left (a) – synthetic PSDM cross-section produced from ***Elastic*** gathers;
Right (b) - synthetic PSDM cross-section produced from ***Visco-elastic*** gathers;
From comparison of a) and b) there can be seen significant effects of ***velocity dispersion (***at distance ~400m) manifesting in relatively ***lower signal frequency.***

❖ Modeling Q-factor Absorption

Modeled permeable corridor with 8m thickness



The ***visco-elastic approximation*** allows to model such complex effects of wave propagation as frequency dependent wave attenuation and velocity dispersion caused by absorbing properties of the medium.

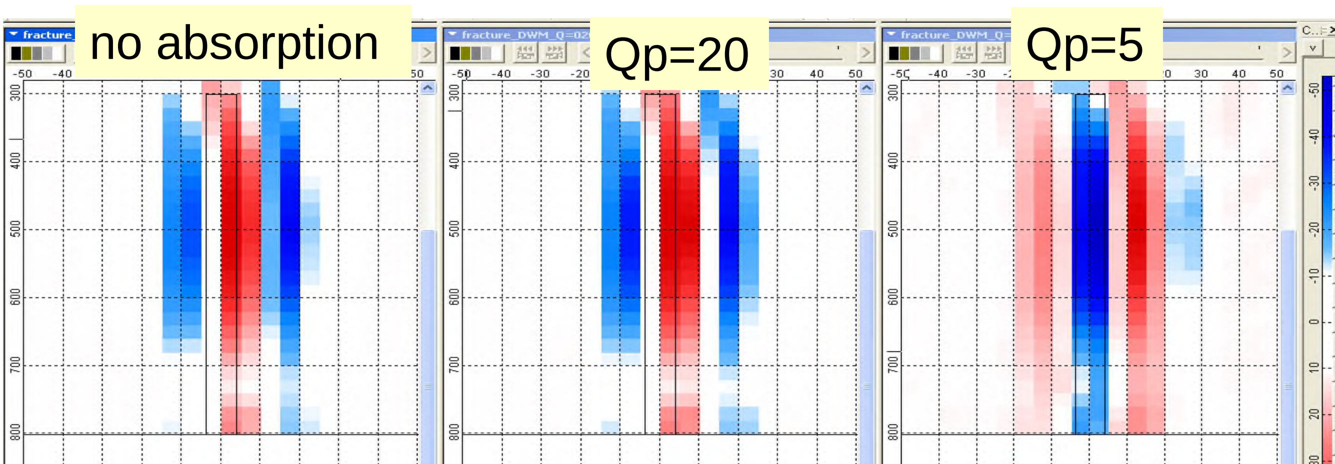
In the Tesseral package the capability of simulating the wave propagation in a viscous-elastic medium enables the users to simulate the P- and S-wave absorption. The theory of absorption inside fractured media shows that wave absorption plays an important role in wave propagation within fluid-saturated fracture rocks in the frequency range of seismic waves.

The estimations of Q for water-saturated fractureallow to expect that it is larger than 20, and for the oil-saturated fracture Q is less than 10.

By using the visco-elastic modeling, it is possible to show that wave absorption changes the wave pattern in the DWM image.

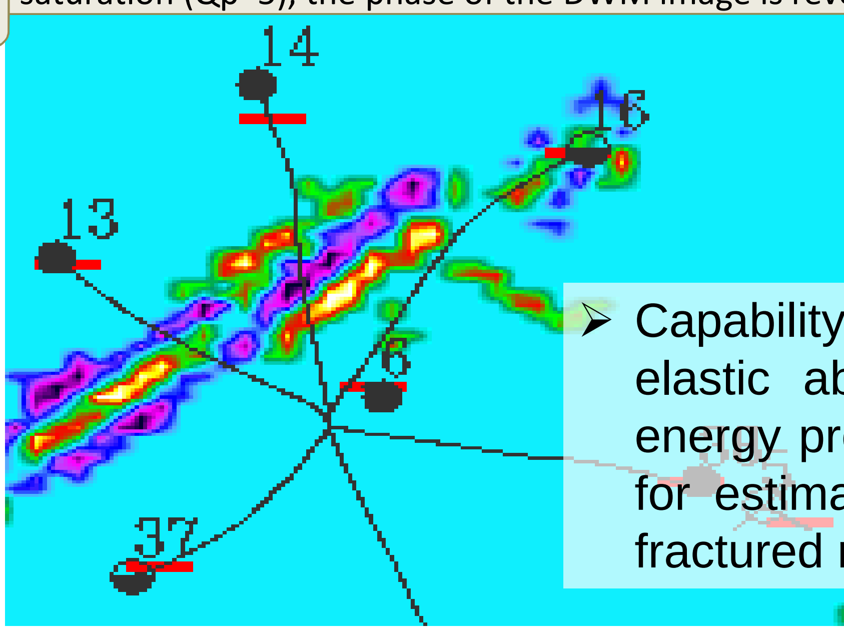
Here, a model with a vertical fractured corridor is shown.

Visco-elastic modeling and DWM image



The DWM image for no absorption (left), Qp=20 (middle) and Qp=5 (right). In case of Qp = 5, the phase the DWM image is reversed.

In *this **Slide***, the DWM images of this corridor are shown, which were obtained by using duplex wave migration. The left DWM image corresponds for the case of no absorption. The middle DWM image is for the case of water-saturation (Qp=20). The right DWM image for the case of oil-saturation (Qp=5). For case of oil-saturation (Qp=5), the phase of the DWM image is reversed.

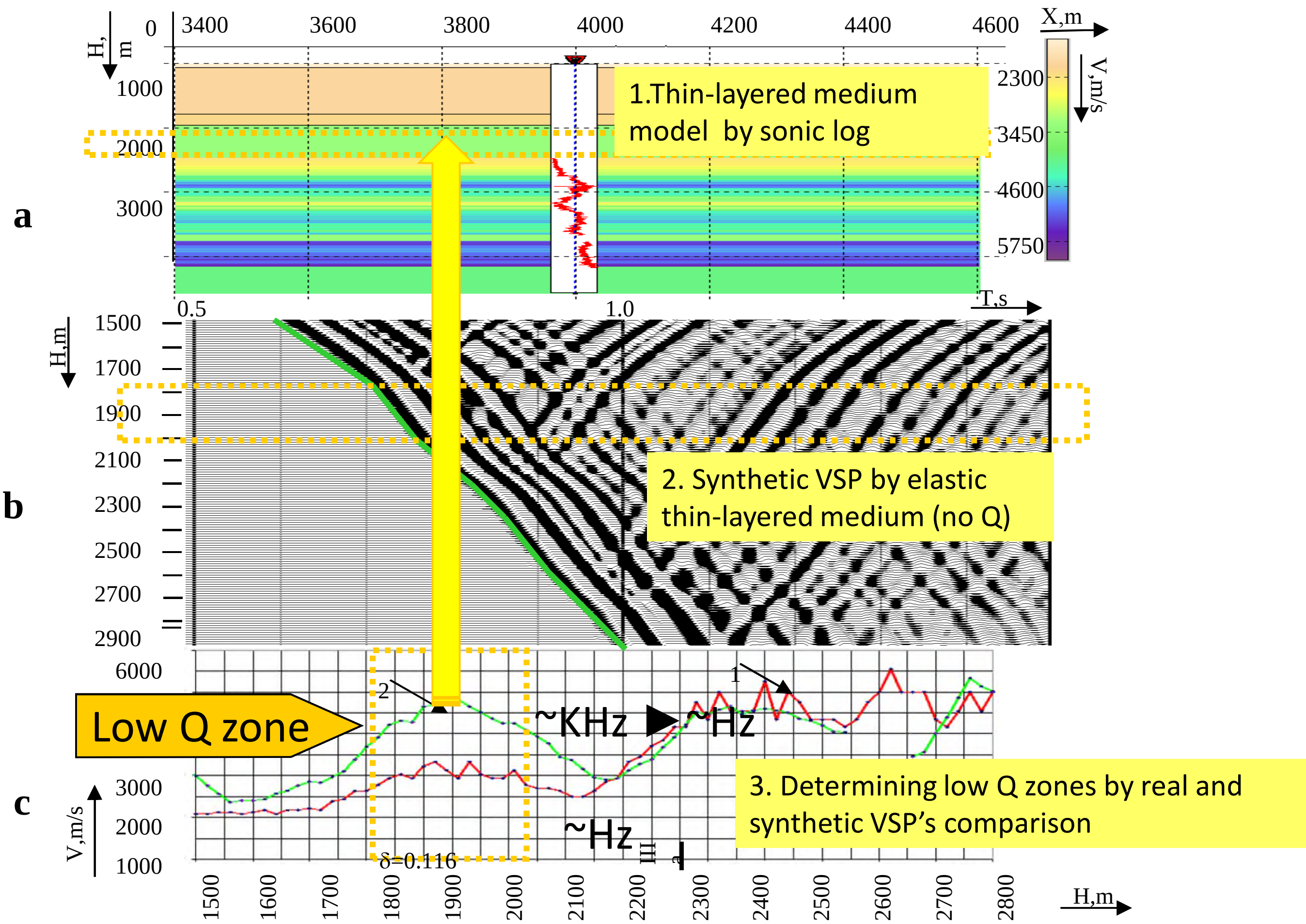


- Capability of modeling visco-elastic absorption of seismic energy provides important tool for estimation of saturation of fractured reservoir.

In this ***Slide***, the stratigraphic slice of the DWM cube is shown for one of reservoir at Timano-Pechorskaya oil province.

The DWM image, where the highly permeable fractured corridor agrees, changes its sign, and this phase reverse may indicate the transition from oil-saturated part to the water-saturated one.

What is effect of low Q zones?



Velocity analysis of the wave propagation for real VSP in comparison with SL → synthetic VSP velocities determined in the well S-2 on the Black Sea shelf : a – thin-layered velocity model by the well SL; b – model shotgather; c – graphics of interval velocities, determined on the base 100 m, V_{VSP}(1-) and $V_{SL \rightarrow VSP}$ (2-).

This Slide illustrates difference between well-logging (10-30 MHz) an seismic frequency data (30-100Hz).

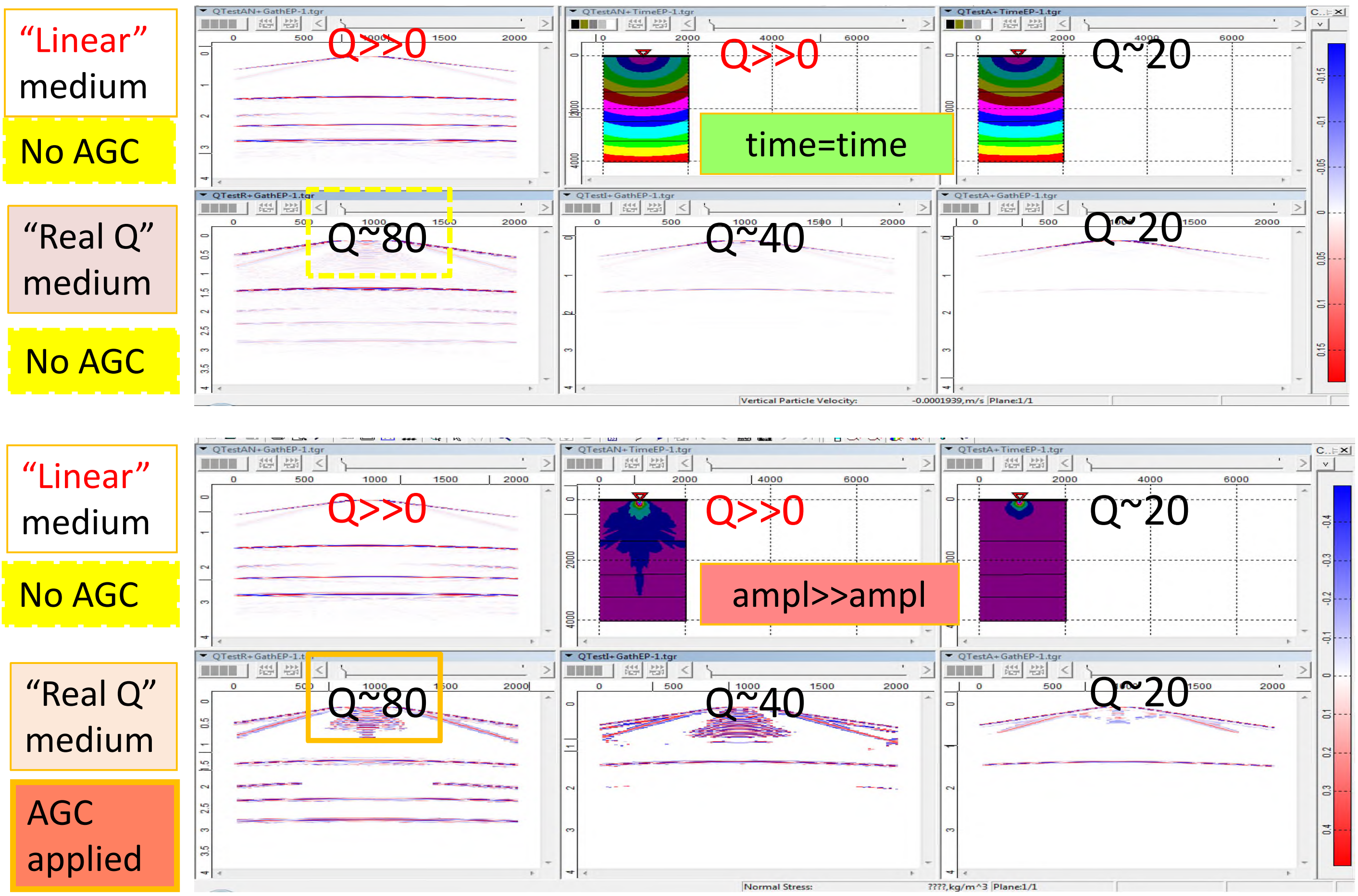
Basing on sonic log (SL) was built thin-layered model (using SL P-velocities).

Then was done VSP survey modeling. Charts of interval velocities show considerable discrepancy between real and synthetic VSP interval velocities.

This is clear indicator of presence of high absorption intervals (low Q – high velocity dispersion), which, in this case, correspond to multi-layered gas deposit.

❖ Modeling Q-factor Absorption

Q-factor Modeling: “Real Q” vs “AGC linearized” pre-stack data



This Slide illustrates difference between linearized seismic signal at using seismic record transformations like AGC and “raw” records.

Conventional seismic modeling using linear wave equation approximations (without absorption of seismic energy) correspond to “*Linear” medium*.

Visco-elastic modeling (and simpler PF-attenuation approach) correspond to ***“Real Q” medium***

The “***Real Q***” approaches in seismic modeling allow to analyse the ***medium frequency-dependent response*** used in processing and interpretation methods **based on the dynamic characteristics of seismic record.**