Modeling of Lamb-Stoneley Tube waves

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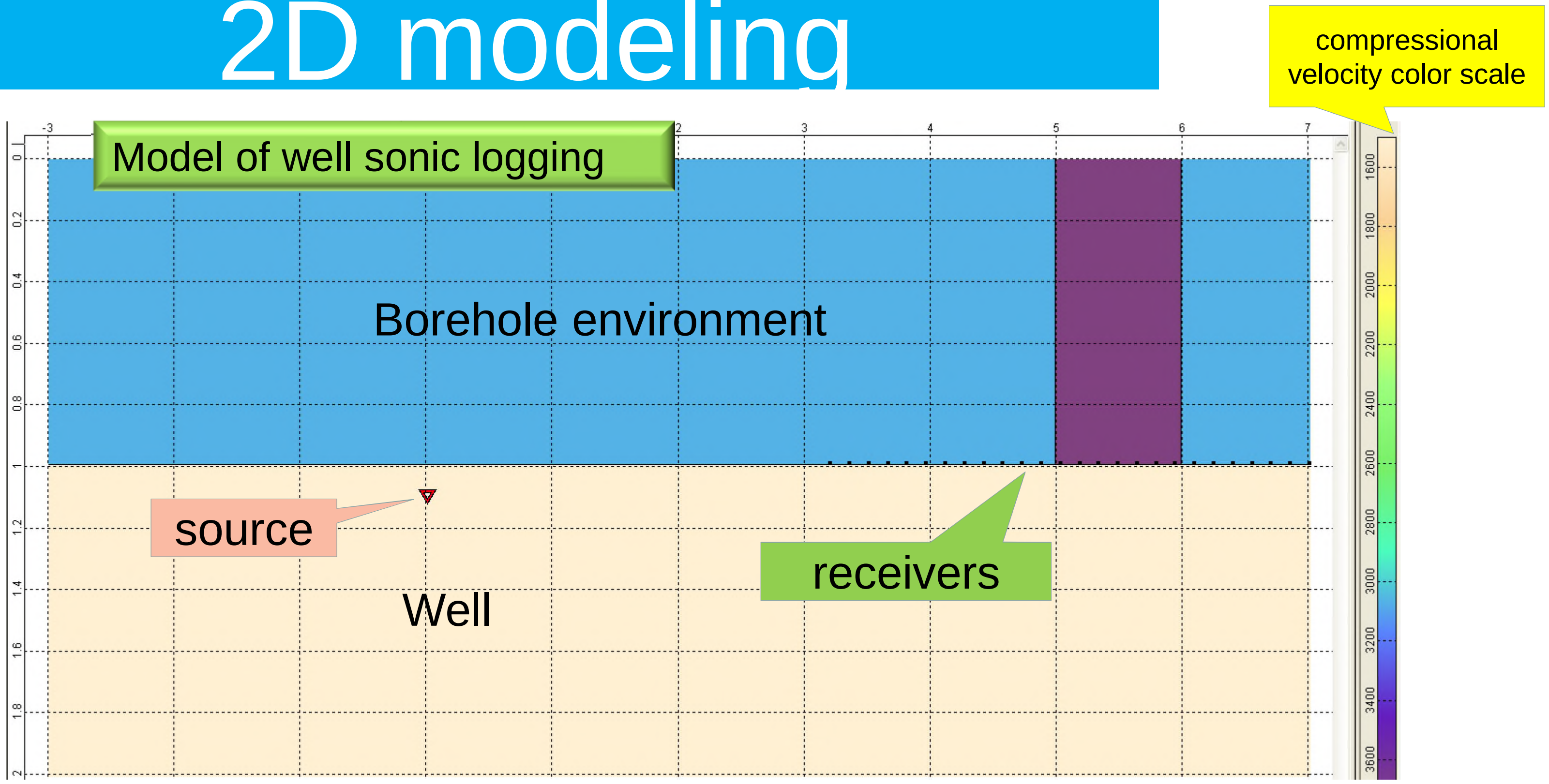
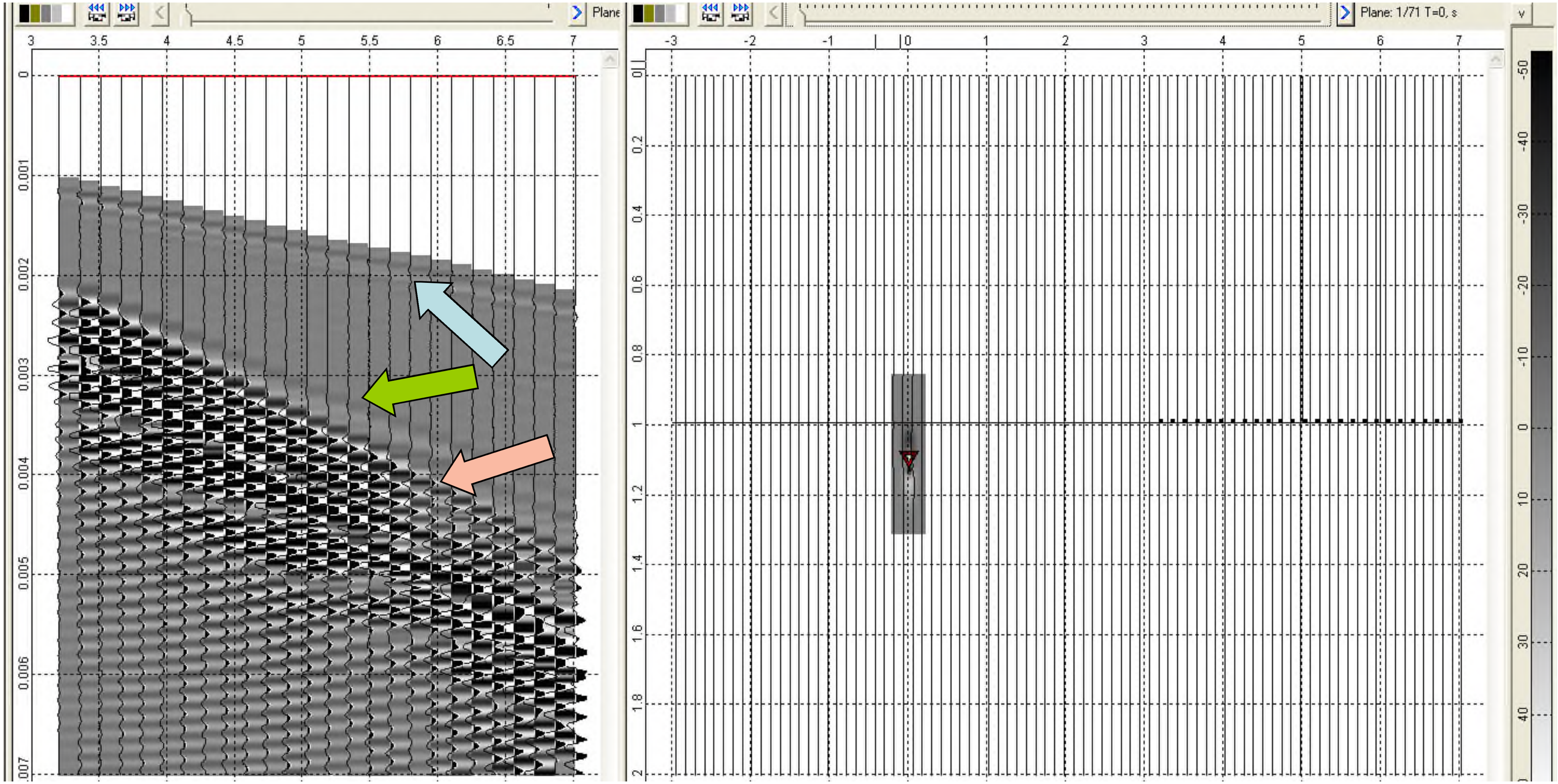
2D modeling



Well is presented horizontally, source at coordinate X=0 inside of the well filled with clay drilling mud (acoustic medium).

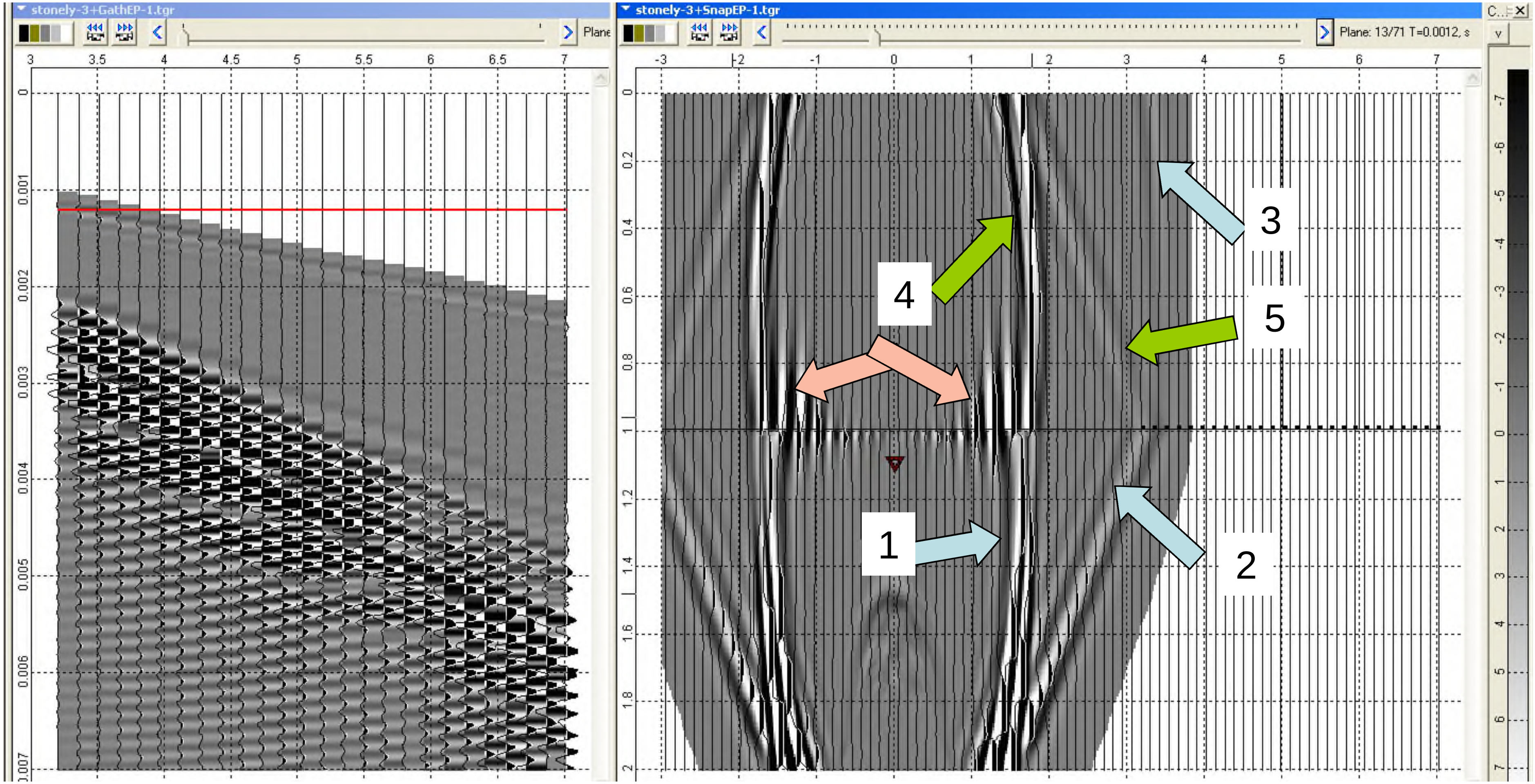
Borehole environment represents homogeneous medium (elastic) complicated with horizontal (with this orientation – vertical) higher velocity layer.

Receivers are positioned at the side of hole from 3 m to 7 m with interval 0.152 m.
Source pick frequency 10 000 Hz.
The computation grid cell size 0.01 m.
Recording sampling 0.000 000 5 sec.



Left picture represents modeled shotgather; right picture – seismic wave field snapshot (at starting)
Red line on shotgather – current time of the snapshot

Blue arrow – compressional wave propagating along side of the borehole
Green arrow – converted shear PS-wave;
Red arrow – Stoneley wave, forming train, which is characteristic for surface waves

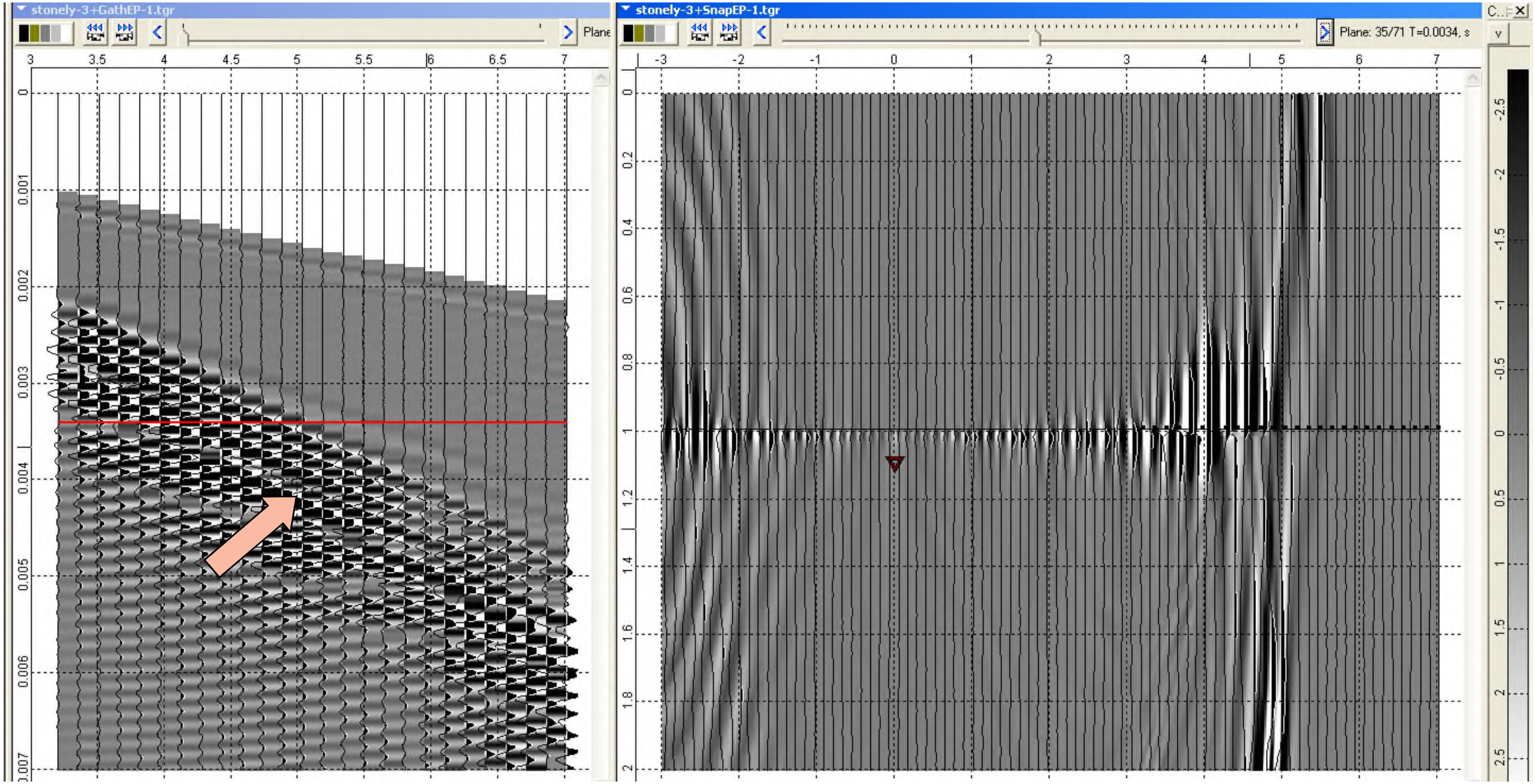


Left picture – snapshot at time 0.0012 sec

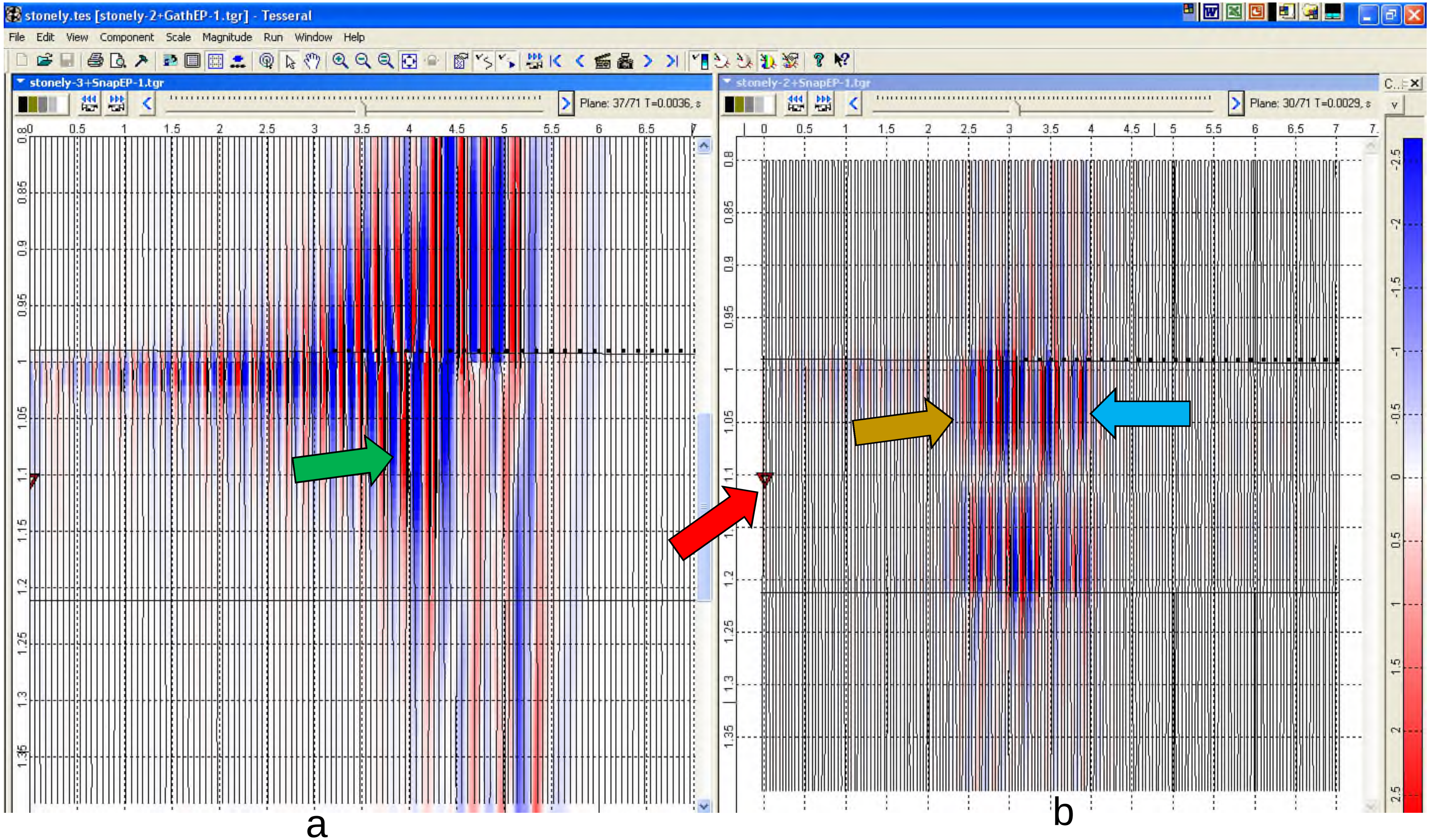
Blue arrows - compressional waves: 1- direct wave from the source, 2- head (conical) wave, 3- direct wave propagating in borehole environment;

Green arrows – converted PS-waves: 4- direct wave propagating in borehole environment, 5- head (conical) wave;

Red arrow – Stoneley waves, sharply attenuating outside of boundary. Intensiveness of those waves is considerably higher than of compressional and converted waves, velocity is smaller than one of shear wave, characteristic feature - forming continuous train.



From this moment (t~ 0.004 sec) reflected from the borehole side converted waves and Stoneley waves begin to interfere. Complicated with such interference part of the shot record is shown with arrow.



a- snapshot in case of one boundary (upper) over source (shown with red arrow) point ; **b**- snapshot in case of two boundaries (analogue of well filled with clay drilling mud (acoustic medium) in which was generated wave.

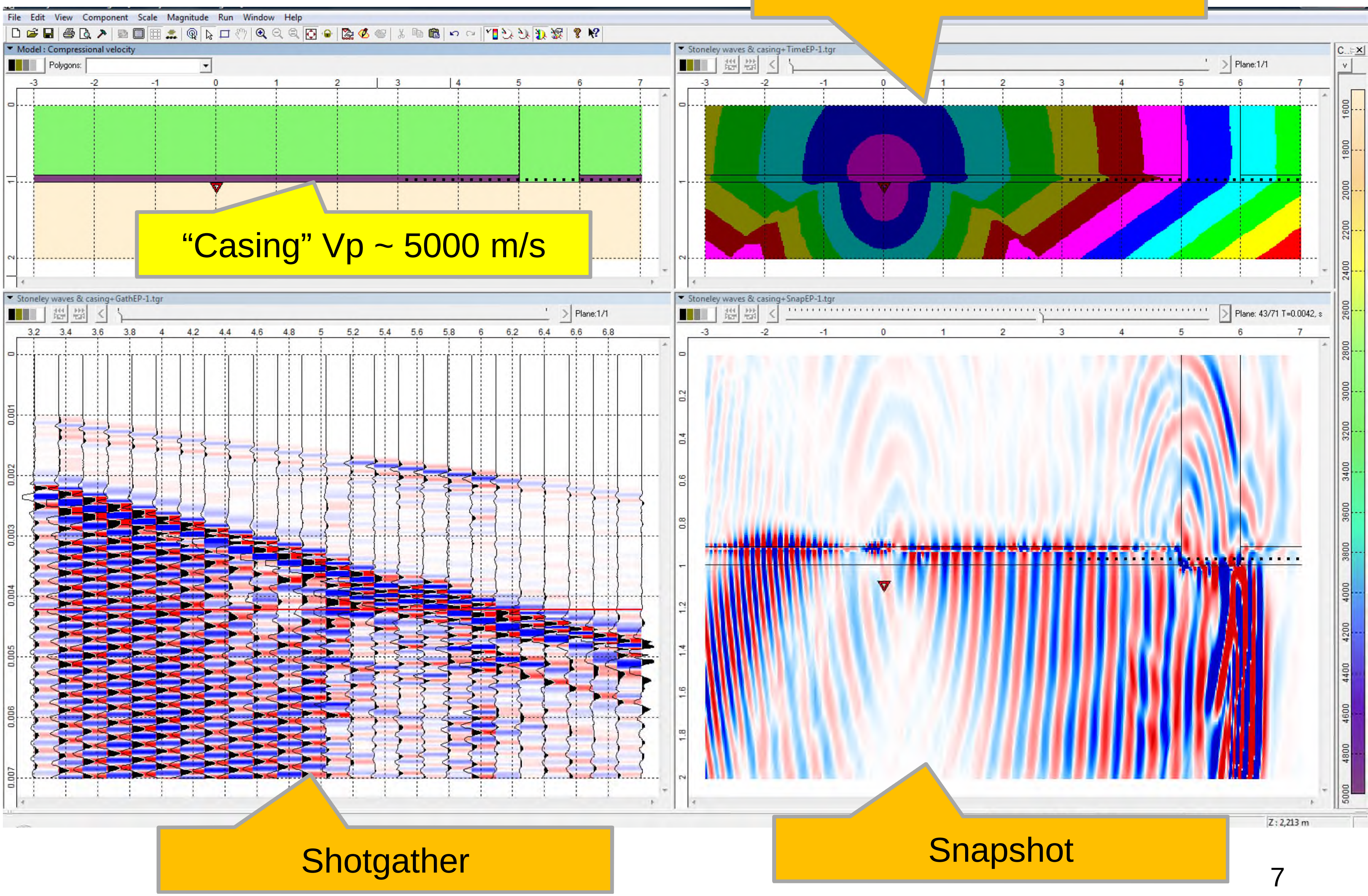
More exactly in this (2D) modeling it is not a cylindrical well but thin infinite hollow.

With blue arrow is shown ***first arrival*** of compressional wave propagating in liquid.

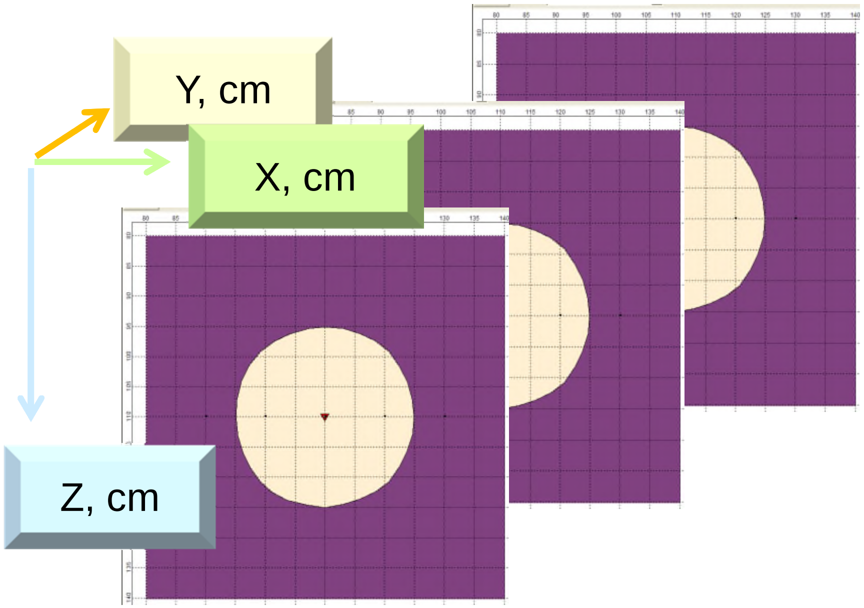
With brown arrow - ***tube wave***, velocity of which is considerably smaller than of compressional wave.

With green arrow are shown ***waves relating to discontinuity***.

Model of well sonic logging “with casing”



2.5D-3C modeling



Model for simulating Lamb- Stoneley tube waves

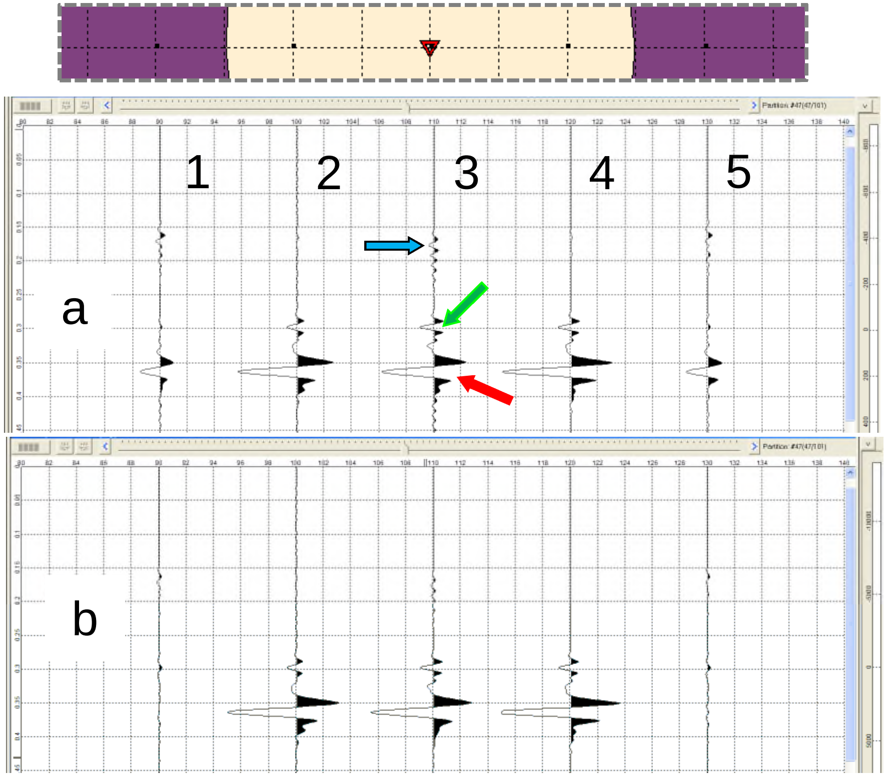
- Model of horizontally-oriented well in homogeneous surrounding medium
- Y-axis is perpendicular to the model image.
- Source peak frequency 50KHz
- Model is scaled to equivalent of 50Hz frequency of the source.
- *Well is filled* with clay drilling mud (acoustic medium).
- Borehole environment represents solid homogeneous medium (elastic) with higher velocity and density

The fact that the 2.5D modeling can simulate wave propagation in 3D space enable modeling the Lamb-Stoneley tube waves.

Theoretically, the velocity and the amplitude of the Lamb-Stoneley wave is depend only on the S-wave velocity inside the casing tube. In case that the well penetrates permeable fractured zone, S-wave velocity is changed, and the Lamb-Stoneley wave can be recorded in broadband acoustic logging.

In *this Slide* , the model of a well is shown, where the Y axis is chosen as the depth, i.e. this is the axis along which the medium parameters are constant locally. In this slide, the cross-section of the well's cylinder is shown, which is located in the X-Z plane. As contrary to the real situation, 5 receivers are deployed along the X axis at each recording depth (Z). Two of them are located outside the well.

The modeling parameters are selected proportionally to the acoustic logging frequencies and dimensions of the well.



Components :

a - Hydropohe (omnidirectional pressure);

b - Y- component of particle movement;

Receivers 1 and 5 are near the well walls in solid rock, 2, 3, 4 – inside well drilling mud.

Arrows:

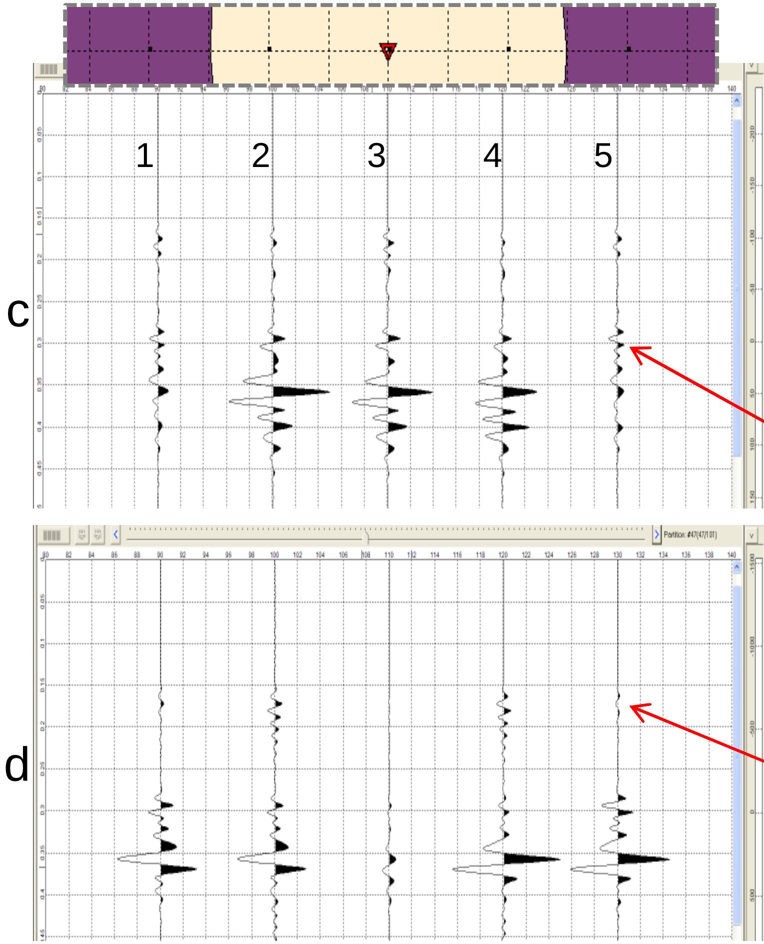
blue – head wave, propagating in rocks,

green – direct wave in water (55 Hz),

Red -– tube wave (30 Hz)

It can be seen from this Slide that the Lamb-Stoneley wave is shear wave, and its velocity is lower than S-wave velocity in a liquid. Intensity of the Lamb-Stoneley wave in this case is higher, and its frequency is lower than the one of the direct waves propagating in the liquid.

It is also possible to observe that the Lamb-Stoneley wave is dramatically attenuated outside the well, and this reveals the well-known fact that it is hard to record such kind of waves by pressing down recording devices into the well's wall.



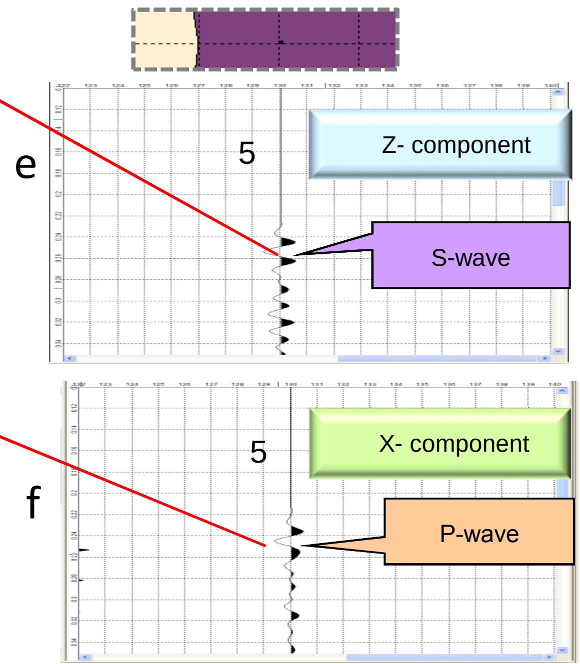
c - Z-component;

d - X-component;

Absolute amplitudes:

Y- component – **14 000;** X – 1 000; Z – 200;

Relatively big value of *Y-component* means than the wave is polarized along propagation direction, i.e. ***is compression*** wave.



For receiver near the well wall inside of solid rock

e - for Z-component – S-wave is recorded

f - for X-component – P-wave is recorded

Arrival of P-wave is earlier(for 50Khz – 10 mcsec) than S-wave by 10 msec .

In *this Slide*, the example of the wave recorded by a pressure unit is shown. Here, the Z-component is shown in the top and the X component is shown at the bottom. Here the intensities of waves (absolute amplitude) for various components are also shown. The strongest signal at Y component is a P-wave arrival, because its sources and receivers are located close to the cylinder axis.