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Advantages and Disadvantages of Surface and Downhole Seismic Illustrated by Processing Results of 3D VSP and 3D+VSP

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SUMMARY

Comparative analysis of Surface Seismic (SS) and VSP shows that each application has its own advantages and disadvantages. Surface Seismic never provides true velocity model and true signature. This is the reason for low resolution and inefficient processing of converted PS waves. In fact modern SS is on the limit of efficiency being still inadequate in many applications. VSP provide true velocities and true signature but quickly loses its efficiency in the vicinity of well. This is shown as comparison between Walkaway and CDP section. Example of 3D+VSP processing results shown that in this combined application signature and velocity model from VSP may be used to improve efficiency of Surface Seismic.

Introduction. Comparative analysis of surface seismic (SS) and VSP shows that each application has its own advantages and disadvantages.

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Example of 3D+VSP processing results shows that in this combined application signature and velocity model from VSP may be used to improve efficiency of surface seismic.

Surface seismic. Today's land seismic (2D and 3D) is a leading and successful technology providing continuous geological models of productive layers.

High quality surface seismic surveys deliver clear images of sub-horizontal media with vertical resolution up to 100 Hz which corresponds to 15-30 m depending on velocity parameters of a section. For such media efficient estimation of physical properties for thick hydrocarbon layers can be made but not for the thin layers.

The distant study of target object is a principal drawback of surface seismic. Inhomogeneity of the medium results in distortion of the response of studied objects on traveling source signal. Exact and detailed information about all inhomogeneities along the ray path "source-object-receiver" is the ultimate requirement when investigating deep objects.

Downhole seismic. Vertical seismic profiling is a kind of transitive method inheriting some properties of both log and surface seismic surveys. Receivers are located inside of the studied medium in a borehole while source(s) may be placed at any point on a surface.

Consequently, VSP is able to provide resolution consistent with that of log surveys when studying near-borehole space. The experimentally confirmed vertical resolution here is about several meters. When dealing with offsets up to 25% of target object depth VSP provides 2-3 times greater resolution compared to surface seismic abilities.

Unfortunately, VSP (and other downhole methods) have their own principal and unremovable drawbacks. Asymmetry of acquisition geometries leads to uncompensatable amplitude distortion induced by non-uniform illumination of interfaces (fig. 1) and impossibility of efficient reduction of multiples.

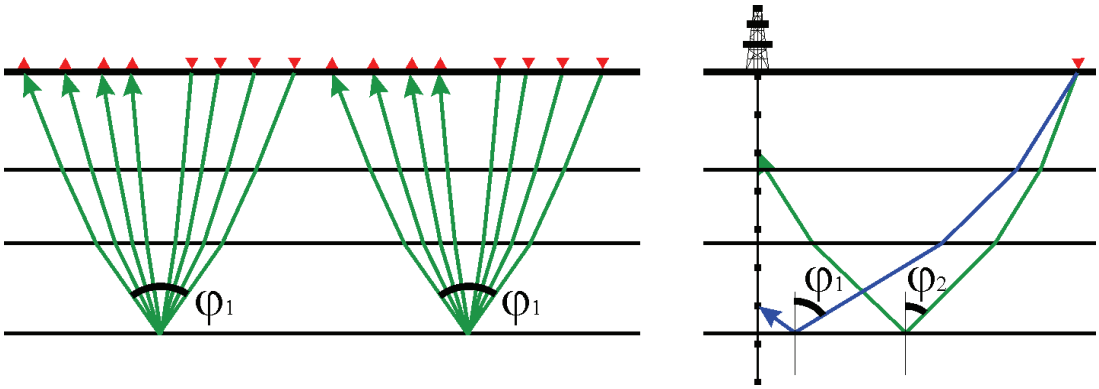

Fig. 1. Symmetric illumination of interfaces in surface seismic (left) and asymmetric illumination in VSP (right)

Surface seismic vs. downhole seismic. Following example shows advantages and disadvantages of results obtained with the use of surface seismic and downhole seismic processing.

Following figure shows: a fragment of CDP section (fig. 2a) walking across the borehole, where VSP was carried out, fragment of section obtained by VSP data (fig. 2c) and amplitude spectra of CDP and VSP images correspondingly (fig. 2b, 2d).

Width of CDP image spectrum is 12-40 Hz and width of VSP spectrum is 12-80 Hz. VSP results resolution is greater than CDP. It allows obtaining more detailed structure of borehole vicinity such as river bed. But quality of VSP results decreases dramatically with grows of distance to borehole.

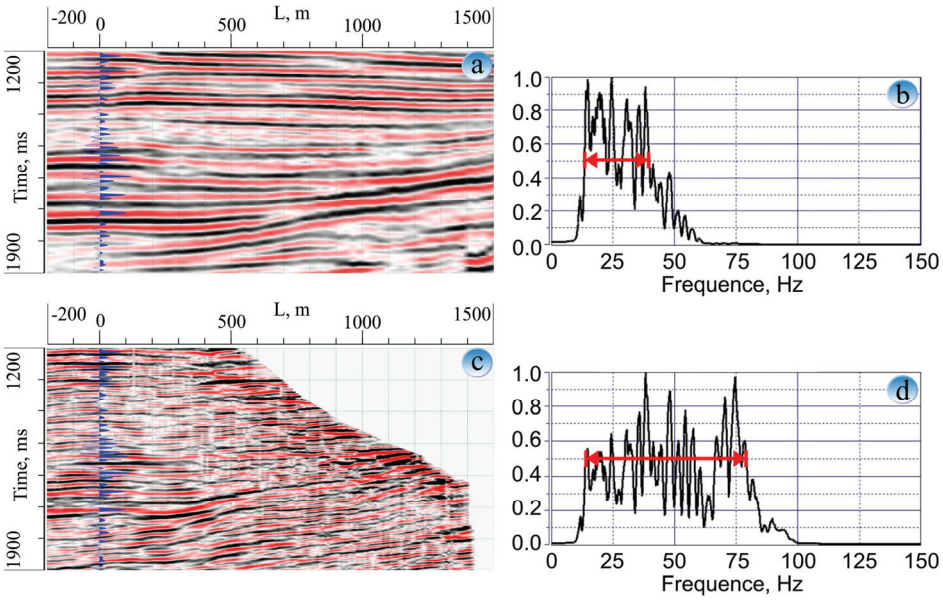

Fig.2. Comparison of results obtained with the use of surface seismic (a, b) and downhole seismic (c, d) processing

Three-dimensional acquisition geometries. Implementation of log and VSP data during interpretation stage of surface seismic data allows to compensate effects of low resolution and lack of detailed information about velocities. However, at present all possibilities of such support have been mostly used and further improvement in resolution and accuracy of seismic exploration needs additional data from more informative acquisition systems.

There is always some amount of wells available in the reservoir area during exploration aimed at efficient extraction of residual hydrocarbon deposits. Three-dimensional acquisition geometries appear when all shots of surface seismic survey are recorded also by downhole geophones in all available wells on the area (fig. 3). Such acquisition system may be referred as 2D/3D+VSP due to only partial (discrete) coverage of the vertical spatial dimension. The proposed acquisition geometries allow for compensation of two disadvantages of surface seismic: uncertainties in signature estimation and velocity distribution recovery.

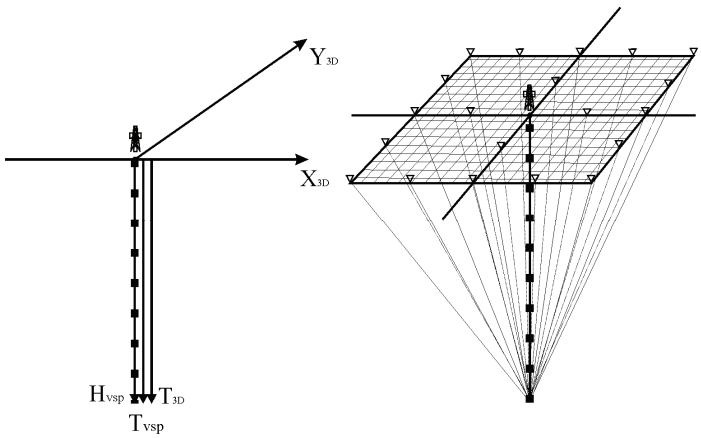

Fig. 3. Conventional VSP (left) and 3D+VSP (right) acquisition geometries

Field tests of combined surface (2D and 3D)-downhole surveys have demonstrated both proclaimed advantages of three-dimensional seismic acquisitions (Tabakov et al., 2003, 2007).

Registration of direct wave shape in the borehole provides compensation of varying shot conditions while arrival times picked at the downhole explicitly provide shot statics and allow to adjust velocity model of the medium (fig. 4, 5).

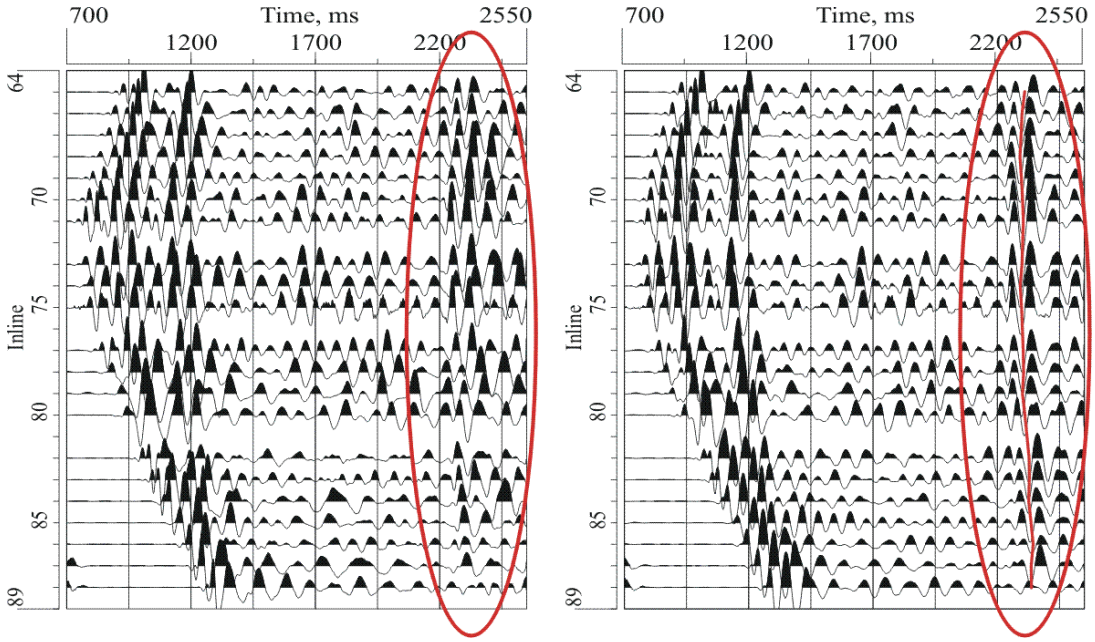

Fig. 4. Compensation of shot statics and impulse shape variation in surface common shot gather in 3D+VSP survey: left – before correction, right – after correction

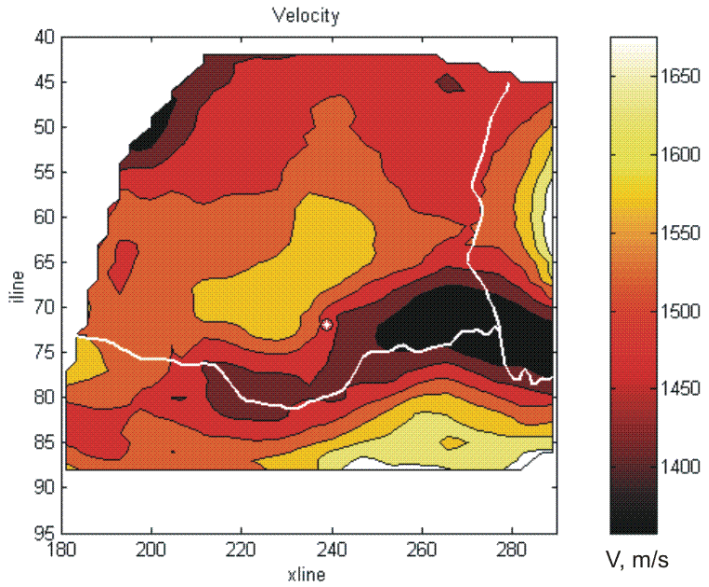

Fig. 5. Adjustment of weathering layer velocities regarding lateral shot statics variation acquired by downhole device in 3D+VSP survey (river bed superimposed in white)

Application of 2D/3D+VSP acquisition and processing techniques helps to improve resolution and reveal some structural features in resulting seismic sections (fig. 6).

With the use of massive downhole receiver arrays it is also possible to solve full inverse kinematic problem in order to estimate true P and S velocity distribution along borehole and thus compensate inhomogeneity of the medium and preserve high resolution of processing results.

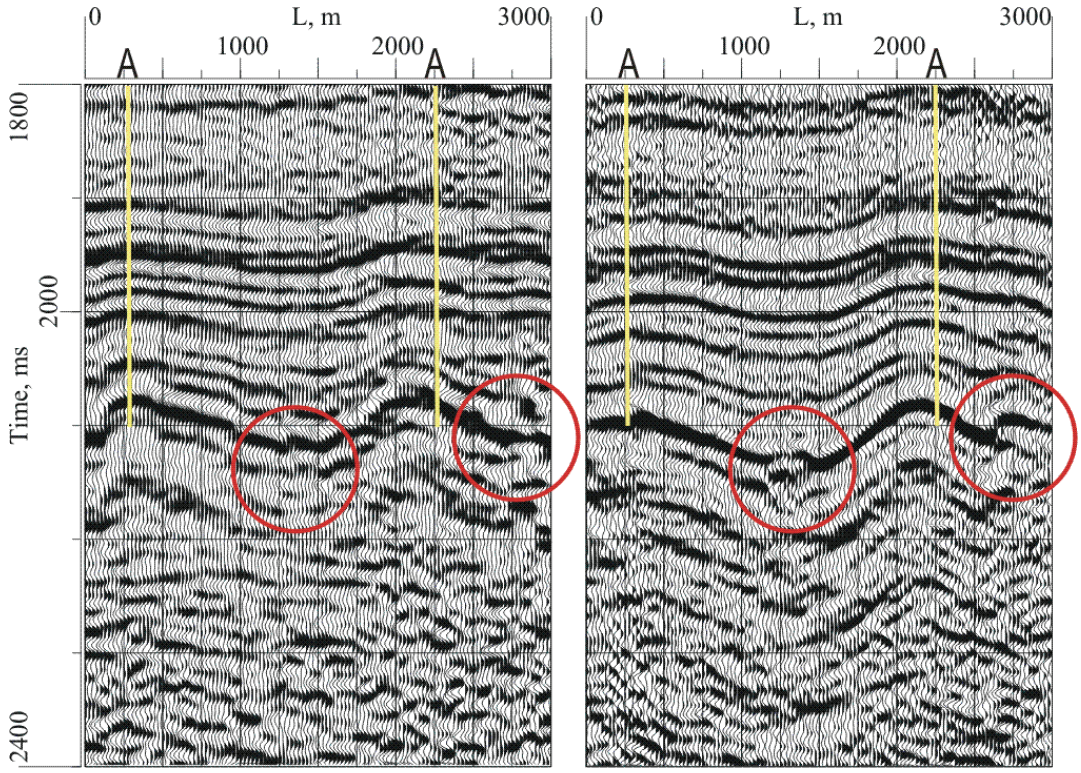

Fig. 6. Results of conventional 3D seismic (left) and 2D+VSP (right) processing compared

Conclusion.

- Both surface and downhole seismic applications have their own advantages and disadvantages and VSP can successfully extend surface seismic.
- To improve efficiency of today's seismic it is reasonable to use combined surface and downhole acquisition geometries.
- The one and only way to realize all advantages of such acquisition system is to use multilevel geophone tools preferable covering all available depth.
- Here is the main advantages of combined acquisition systems:
    1. increasing of surface seismic resolution by using of true signature for deconvolution;
    2. correct structure recovering and converted shear wave processing with the use of 3D true velocity model of medium;
    3. higher resolution due to inphase stacking with the use of true velocity model.

References.

1. Tabakov, A.A., Baranov, K.V., Eliseev, V.L., Reshetnikov, A.V. and Kopchikov, A.V. [2006] About Principles and Actuality of Combining Surface and Downhole Acquisition Geometries (3D+VSP, 2D+VSP). *6th International Conference and Exhibition "Galperin Readings – VSP and 3D Acquisition Systems"*. Moscow, Abstracts, 7-9.
2. Tabakov, A.A., Kashik, A.S., Gogonenkov, G.N. and Baranov, K.V. [2003] 2D, 3D+VSP Acquisition Geometries Combining Surface and Downhole Measurements. *International Conference and Exhibition "Geophysics of the XXI Century – Leap into the Future"*. Moscow, Extended Abstracts, OS2.