ГеоВерс

Amsterdam|'09

HDS
HIGH DEFINITION SEISMIC

GEOVERS Ltd.
GERS JSC
UNIS Ltd.

The uncompromising innovation technology

http://www.geovers.com
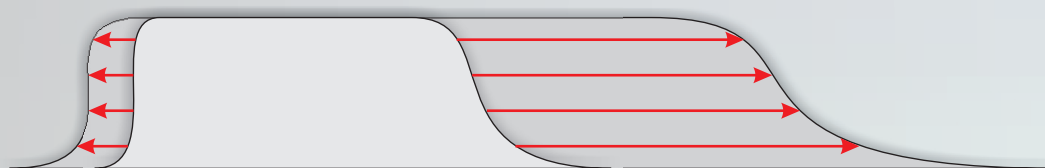
HDS HIGH DEFINITION SEISMIC PREFACE

GEOVERS Ltd.
Company Profile

GEOVERS Ltd. works for mathematical methods and programs development for VSP and surface seismic data processing and also provides service for processing and interpretation.

Area of interests includes questions of waves selection and processing, statics correction, direct and inverse kinematic and dynamic problems, methods of ray tracing and finite difference for modelling and migration in 1D, 2D and 3D models. Special attention is paid to development of combined methods for simultaneous surface and downhole seismic observations and automatic and intellectual methods of seismic data processing.

The company accumulated and uses the experience of several dozen years of research and geophysical applications. The company has own original software system UNIVERS and works on the market of software and service from 2001.

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Integrated land seismic and VSP survey geometries offer improved imaging solution

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ABSTRACT

The increasing demand for detailed exploration of small hydrocarbon deposits and complicated structures can not always be met by means of conventional seismic surveys such as surface 2D or 3D seismic or standalone VSP as they feature a number of principal limitations. Surface seismic (especially when carried out in complicated topographic conditions) suffers from near-surface uncertainties and strongly varying shot conditions which often lead to misinterpretation and decrease in resolution. VSP in its nature provides for higher resolution but can be held only at fixed directions. Furthermore, asymmetry of observation geometry in VSP causes uncompensatable amplitude distortions on resulting seismic images.

We propose integrated surface-downhole acquisition geometries that feature simultaneous seismic observations at the Earth's surface (just like in conventional land seismic) and at the bottom of a borehole which is located in investigated area. Having records from the downhole device we are able to directly control and correct shot statics and impulse shape variation in surface seismic data. Also kinematic inversion may be implemented on arrival times at the downhole device delivering lateral velocity model variations which can be used for depth imaging.

The acquisition technology called 3D+VSP or 2D+VSP has been tested several times in real field seismic surveys and has been proven to manifest the proclaimed advantages.

INTRODUCTION

Oil and gas deposits are usually located in the limited depth range occupied by sediments. Therefore their potential resources are also limited while temps of extraction have been tending to grow up constantly. At the same time, all easily accessible territories have been explored enough to such extent that no large reservoirs have been discovered inrecent years. When ar ranging rational and economic scheme of small deposits development and facing complicated seismic and geological conditions the need for accurate and detailed reservoir description dramatically increases. Similar requirements arise when dealing with residual hydrocarbon deposits.

The key problem may be formulated as the following. Conventional seismic exploration technologies with their current informational value are at the edge of being of no use in investigation of small deposits and additional studies of mature reservoirs (Tabakov, 2005).

SURFACE SEISMICS

Today's land seismic (2D and 3D) is a leading and successful technology providing for a construction of 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.

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.

VERTICAL SEISMIC FROFILING

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 first meters. When dealing with offsets up to 25% of target object depth VSP delivers 2-3 times greater resolution compared to surface seismic abilities.

Unfortunately, VSP features its own principal and unremovable drawback. Asymmetry of acquisition geometries leads to uncompensated amplitude distortion induced by non-uniform illumination of interfaces and impossibility of efficient reduction of multiples.

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 exhausted which stops further improvement in resolution and accuracy of seismic exploration.

3-DEMENSIONAL ACQUISITION GEOMETRIES

There is always some pretty amount of wells available in the reservoir area during exploration aimed at efficient extraction of residual hydrocarbon deposits. Three-dimensional acquisition geometries appear when together with land seismic survey all excitations are registered inside one or several boreholes (Fig. 1). 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 impulse shape estimation and velocity distribution recovery.
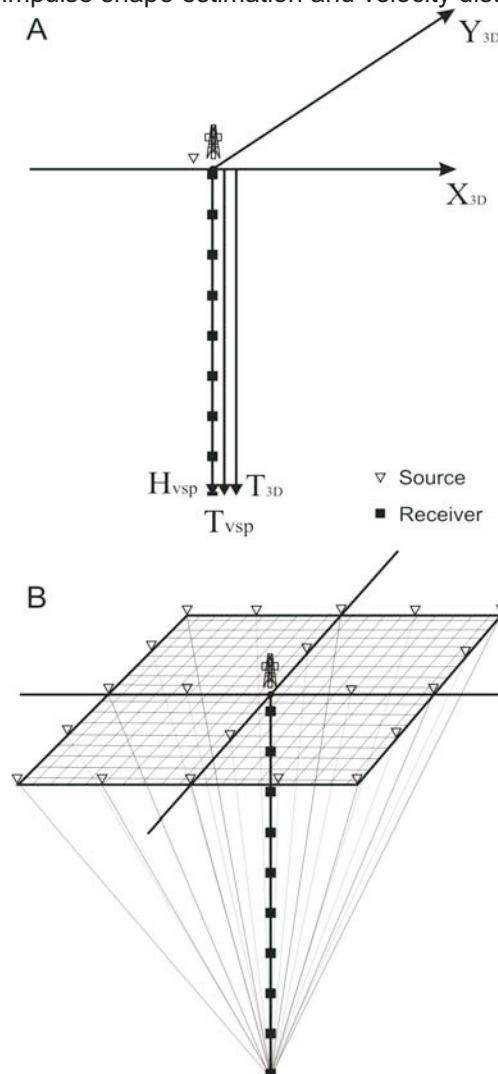
Figure 1. Conventional VSP (A) and 3D+VSP (B) acquisition geometries

Field tests of combined surface (2D and 3D)-downhole surveys have demonstrated both proclaimed advantages of three-dimensional seismic acquisitions (Tabakov et al., 2003). Registration of direct impulse shape in the borehole provides for compensation of varying shot conditions while arrival times picked at the downhole explicitly deliver shot statics and allow to adjust velocity model of the medium (Fig. 2, 3).
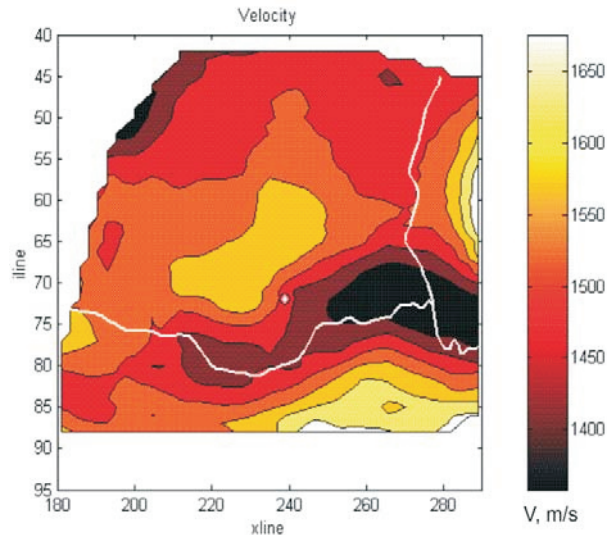

Figure 2. Adjustment of weathering layer velocities regarding lateral shot statics variation acquired by downhole device in 3D+VSP survey (river bed superimposed in white).

Fig. 4 illustrates velocity model adjustment. Fig.4.A demonstrates effective velocity model obtained from surface data that provides getting high quality seismic images (fig.4.B). However, downhole receiver record reveals considerable difference in first break times from calculated by the model (fig.4.D). It means the velocity model doesn't depict the real media exactly, and therefore it leads to some distortions at seismic images. The main reason for discrepancy in that case is salt dome in subsurface area. The first arrival times recorded by downhole receiver allow correcting the salt dome geometry correcting by solving of inverse kinematic problem (fig.4.E) leading to significant decrease of the discrepancy (fig.4.F).

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 "opacity" of the medium and preserve high resolution of processing results.

Application of 2D/3D+VSP acquisition and processing techniques helps to improve resolution and reveal some structural features in resulting seismic sections (Fig. 5).
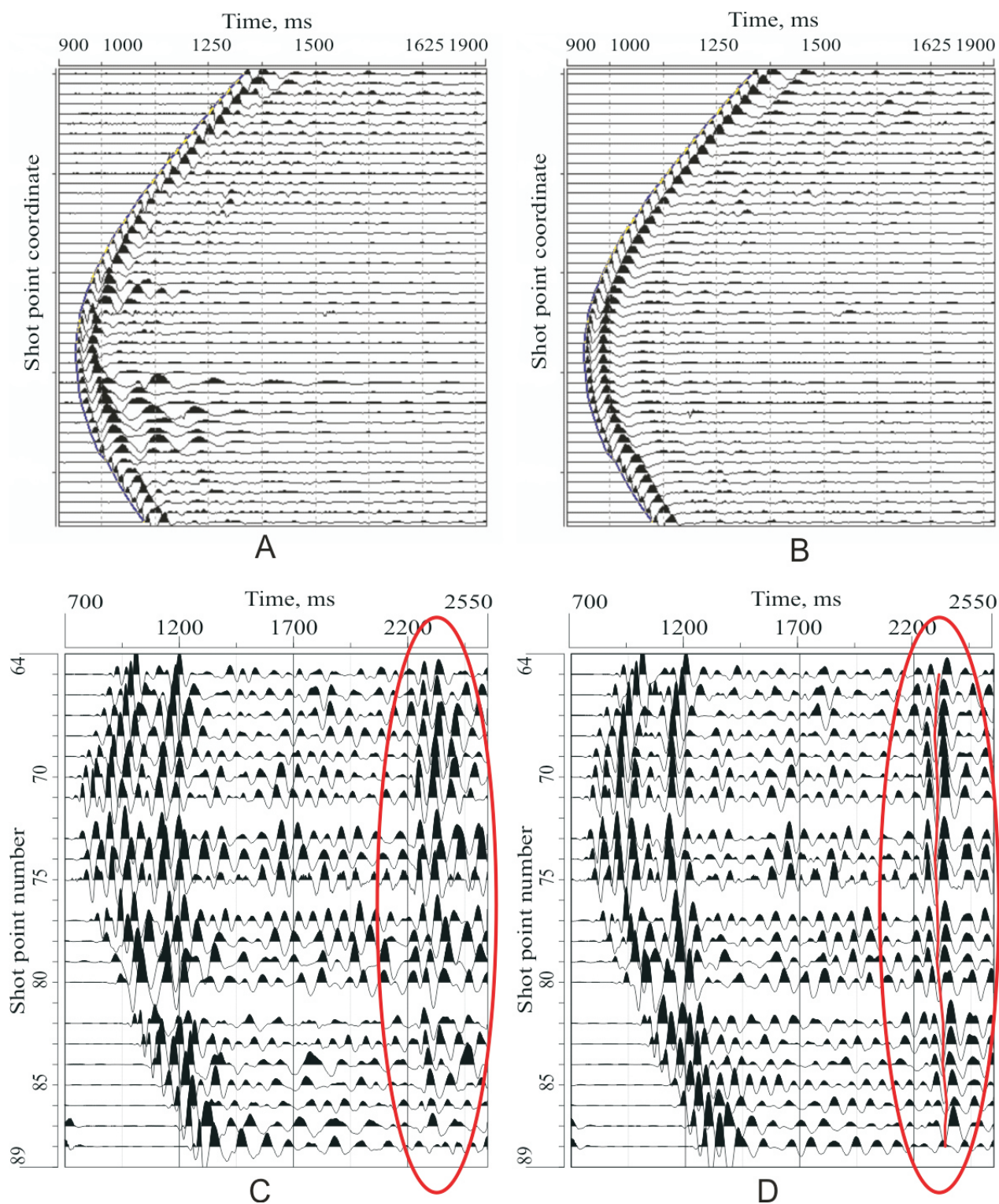
3

Figure 3. Correction of shot statics and impulse shape variation in 3D+VSP survey: A – raw downhole data; B - downhole data after correction; C - surface common shot gather before correction, D – surface common shot gather after correction.
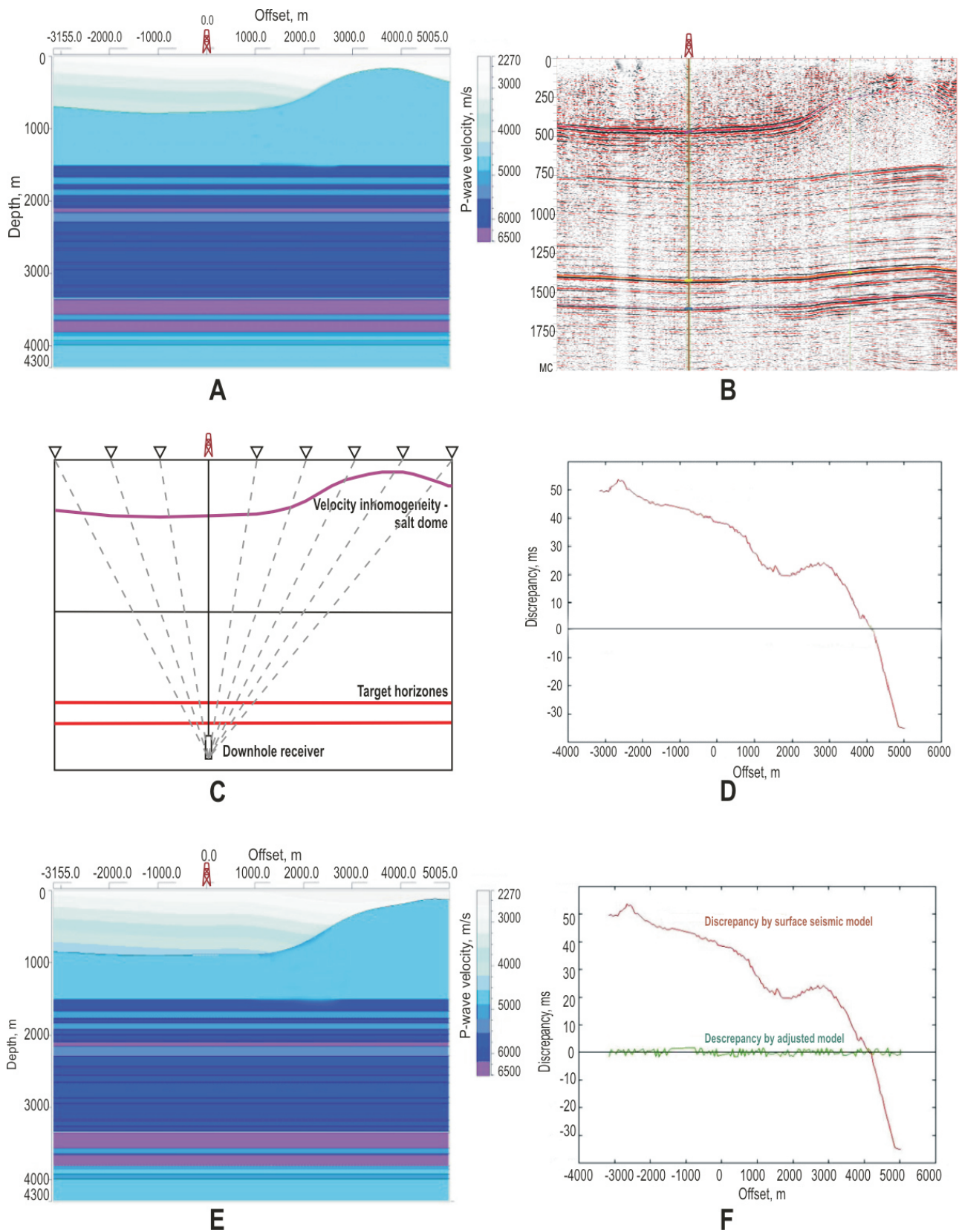
Figure 4. Velocity model adjustment in 3D+VSP survey: A - effective velocity model obtained from surface seismics; B – a 2D surface seismic image; C – 3D+VSP acquisition scheme; D – discrepancy in real and synthetic first arrival times; E – velocity model obtained by inverse kinematic problem solving for first break hodograph picked by downhole data; F – discrepancy in real and synthetic first arrival times before model adjustment and after it.
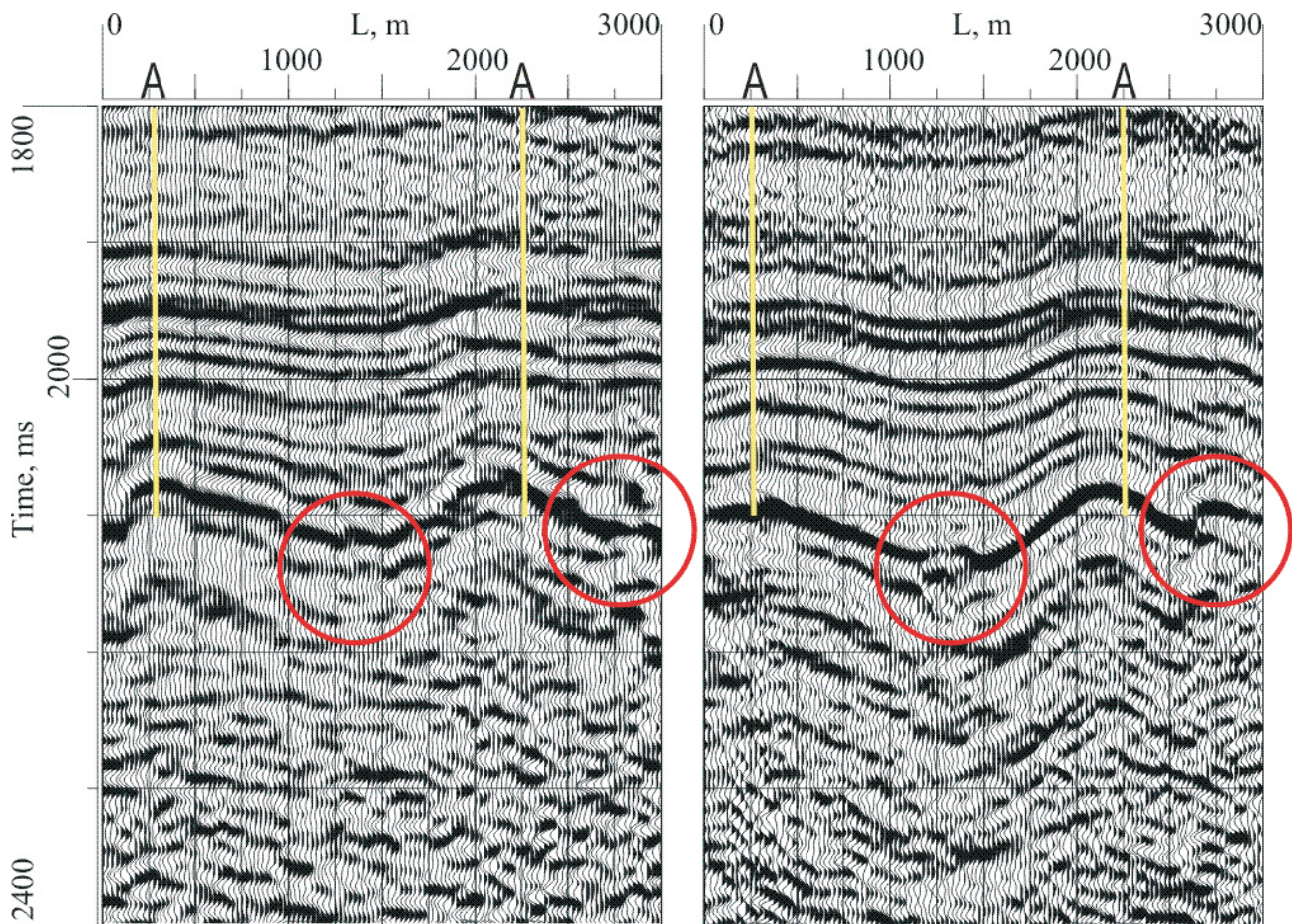
Figure 5. Results of conventional 3D seismic (left) and 2D+VSP (right) processing compared.

CONCLUSIONS

Modern state of hydrocarbon resources and exploitation temps of oil deposits demand for significant increase in resolution and accuracy of seismic studies of productive layers to successfully deal with complicated reservoirs and residual deposits. The proposed concept of integrated three-dimensional acquisition geometries (2D/3D+VSP) allow to combine strong features of both surface seismic and VSP and extend informational value of seismic exploration.

REFERENCES

Tabakov, A.A., [2005], 3D acquisition geometry and model based processing in seismic exploration – the response to challenges of oil industry in the XXI century. 5th Conference and Exhibition "Gal'perin Readings", Moscow, Abstracts. Pp.8-12.

Tabakov, A.A., Kashik, A.S., Gogonenkov, G.N., Baranov, K.V., [2003], 2D+VSP, 3D+VSP acquisition geometries combining surface and downhole measurements. International Conference and Exhibition "Geophysics of the XXI Century – Leap into the Future", Moscow, Expanded Abstracts. OS2.
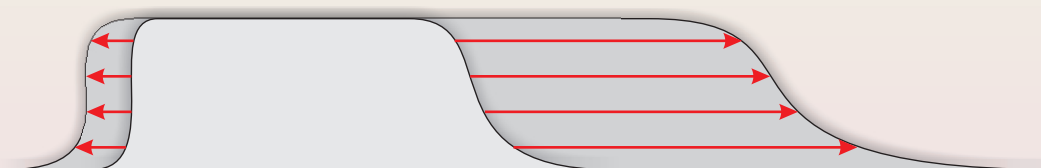
HDS HIGH DEFINITION SEISMIC

СВЧ СЕЙСМОРАЗВЕДКА ВЫСОКОЙ ЧЕТКОСТИ

The uncompromising innovation technology
Бескомпромиссная инновационная технология

Field acquisition
Covers the whole available 3D space of interest

➢ HDS geometry
- 3D acquisition geometry (3D+VSP)   2

➢ HDS geophone
- 3C inside digitizing, no infield array mixing   3
- Non-resonance geophone clamping to ground and well

Processing
Iterative inversion controlled by artificial intelligence

➢ HDS statics
- POLYCOR static calculation   4

➢ HDS wavefield decomposition
- Full model-based iterative analysis of wave fields with model estimation for each type of wave   5
- Fragmented frequency band processing

➢ HDS deconvolution
- Statistically consistent 4-factor deconvolution   6

➢ HDS velocities
- True P, S velocity model   7
- Controlled relation between static corrections and near surface velocity model

➢ HDS migration
- Imaging through vector migration with true velocity model   8

➢ HDS technology
- Processing based on concept of artificial intelligence   9

HDS GEOMETRY

HIGH DEFINITION SEISMIC

3D acquisition geometry (2D+VSP)
Трехмерная система наблюдений (2D+ВСП)

Features

➢ 2D+VSP (true 3D) acquisition geometry

➢ Non-resonance clamping of surface, bottom and downhole geophone

➢ Unlimited number of surface, bottom and downhole geophones

HDS geometry | Survey scheme example

HDS GEOPHONE
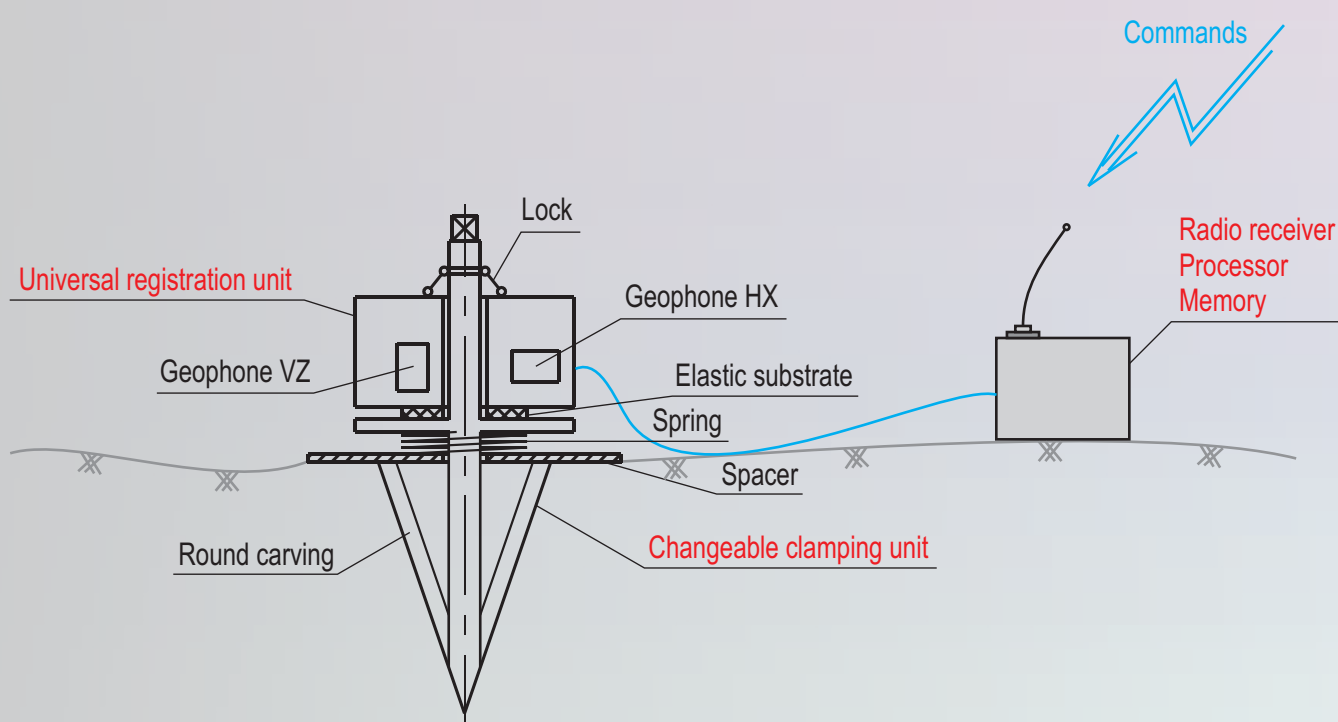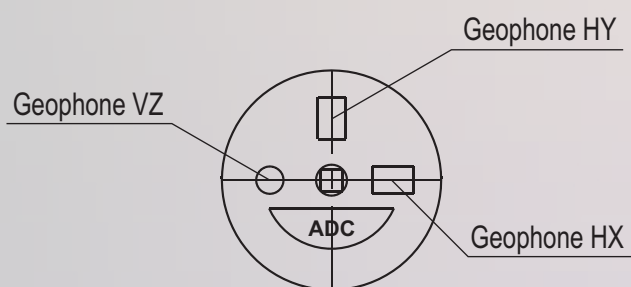### HIGH DEFINITION SEISMIC
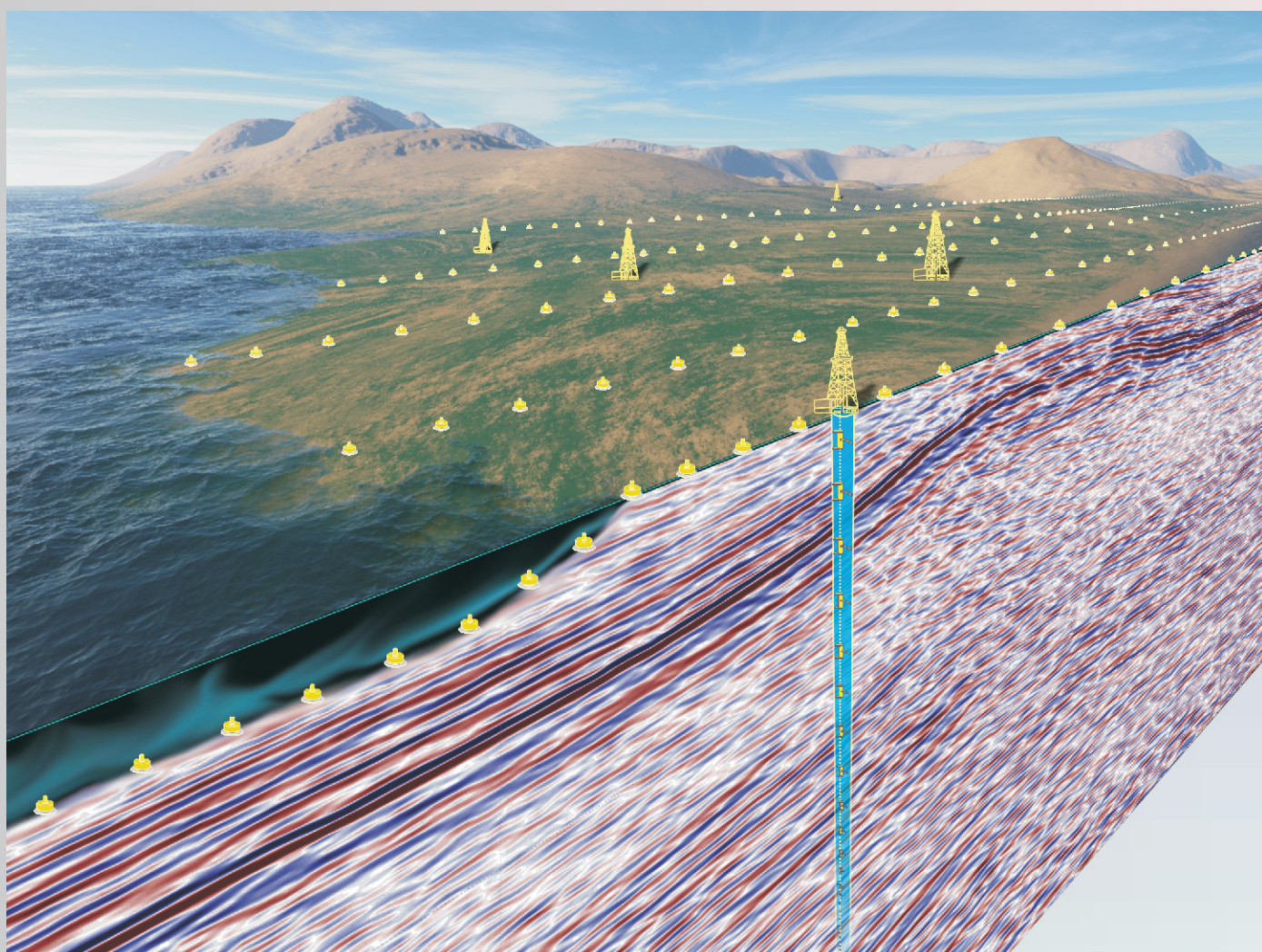
3C inside digitizing, no infield array mixing
Non-resonance geophone clamping to ground and well
Трехкомпонентная внутренняя оцифровка, без группирования в поле
Нерезонансный контакт геофонов с грунтом и стенкой скважины

Key features

➢ Standalone geophone registration unit

➢ Non-resonance clamping to ground

➢ Changeable clamping unit to adopt for a particular ground
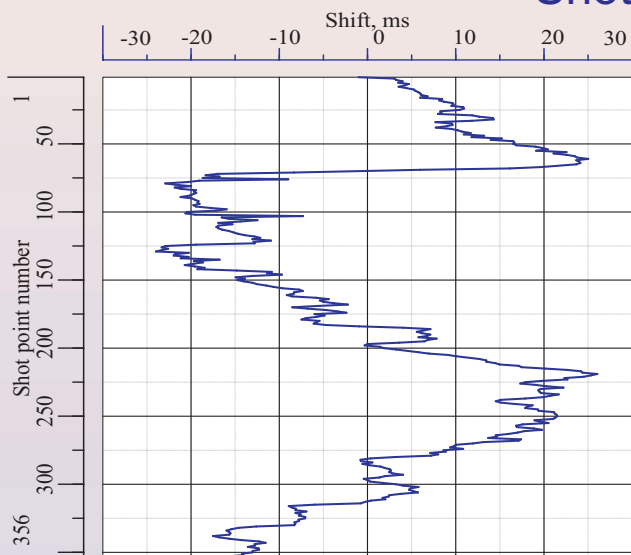
HDS geophone | Schematic design

Geophone HY

Geophone VZ

Geophone HX

ADC

Commands

Radio receiver
Processor
Memory

Lock

Universal registration unit

Geophone HX

Geophone VZ

Elastic substrate

Spring

Spacer

Round carving

Changeable clamping unit

HDS STATICS

POLYCOR static calculation
Расчет статики по методу «ПОЛИКОР»

Main properties:

Independence of shot- and receiver-based corrections

Independence of shifts range (100ms)

Non-iterative algorithm

Velocity independence
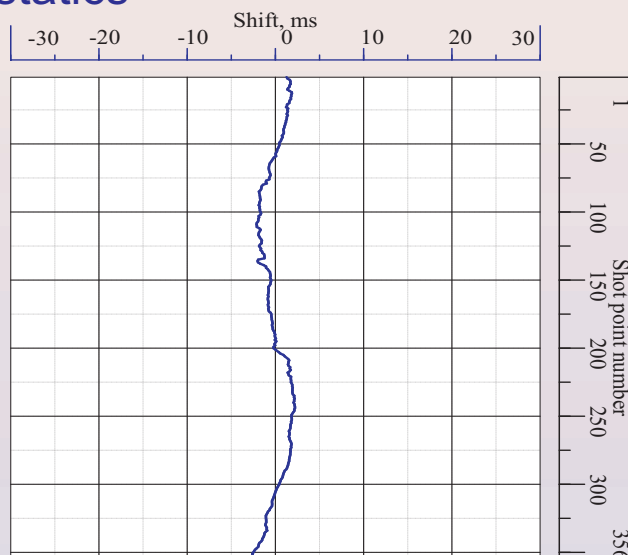
High-, medium- and low-frequency corrections at one step
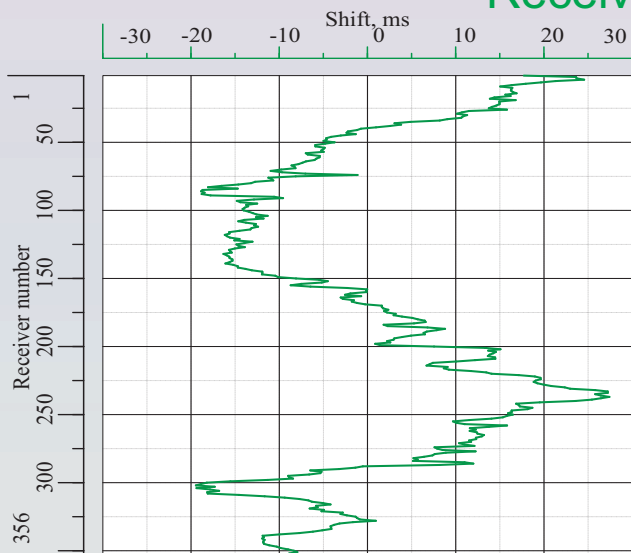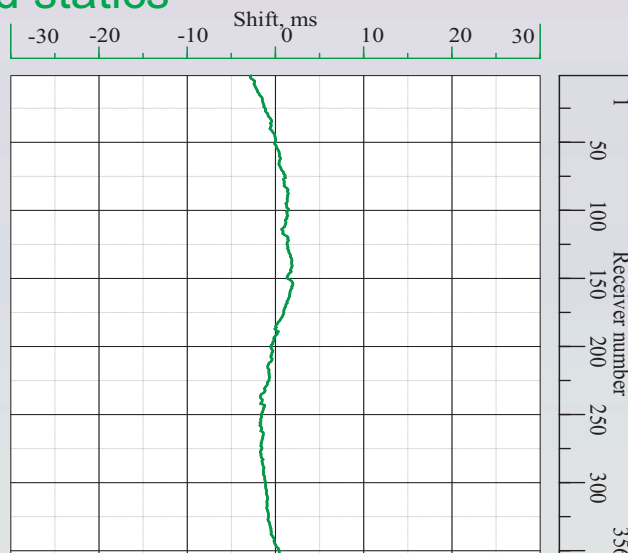
Original static shifts

Residual static shifts

Shot-based-statics

ONE

Receiver-based statics

STEP
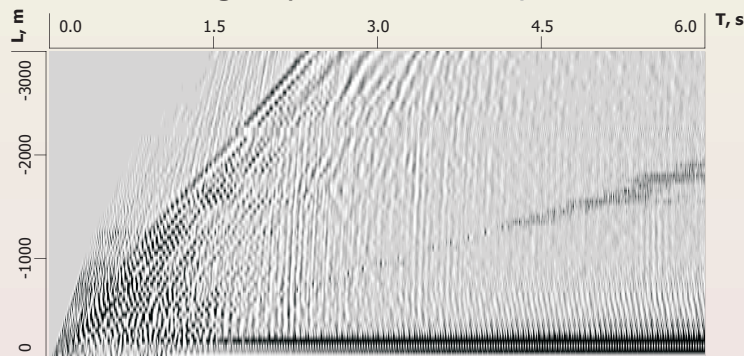
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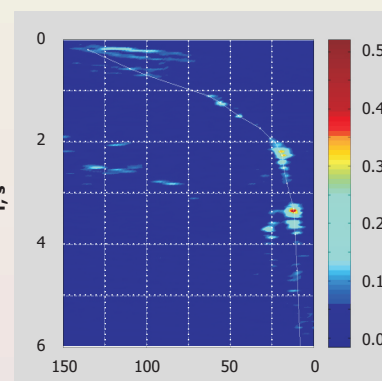
WAVEFIELD DECOMPOSITION

Full model-based iterative analysis of wave fields with model estimation for each type of wave

Полный модель-базированный итеративный анализ волновых полей с оценкой модели для каждого типа волн
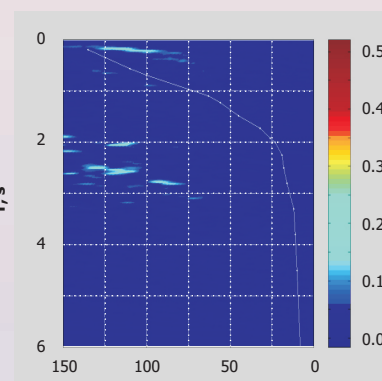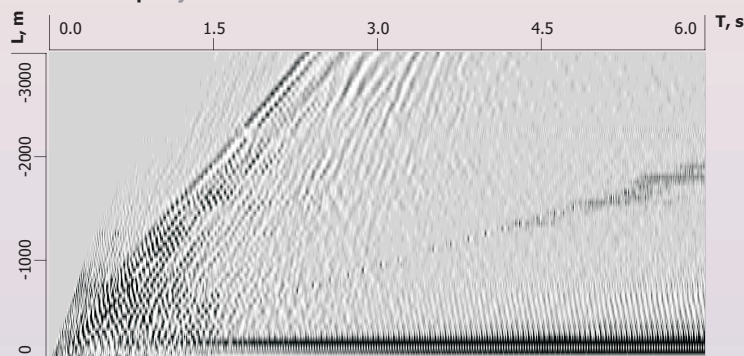
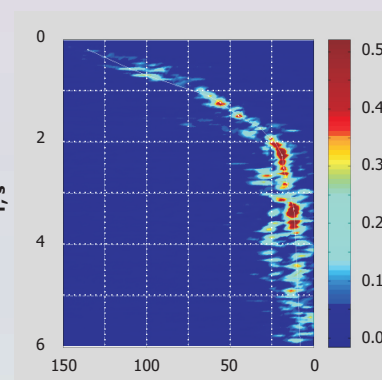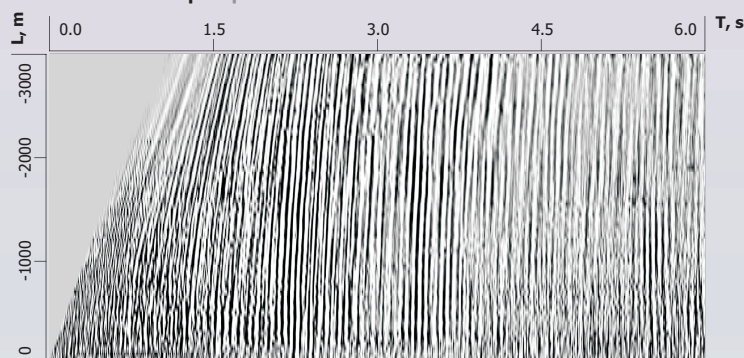**Source seismogram | Исходная сейсмограмма**

**Coherency | Когерентность**

Noises | Шумы

Reflections | Отражения

Hyperbola | Гипербола, (ms / 1000 m)

HDS HIGH DEFINITION SEISMIC — DECONVOLUTION

Statistically consistent 4-factor deconvolution
Статистически представительная четырехфакторная деконволюция

Estimation

1. Parametric estimation of absorption vs offset
2. Parametric compensation of absorption vs offset
3. Parametric estimation of absorption vs time
4. Parametric compensation of absorption vs time
5. Iterative separation of Basic, SP and RP factors

Application

➢ Synthesis of statically consistent autocorrelations combining of Basic, SP, RP, offset and time

➢ Application of prediction error statistically consistent time varying operator
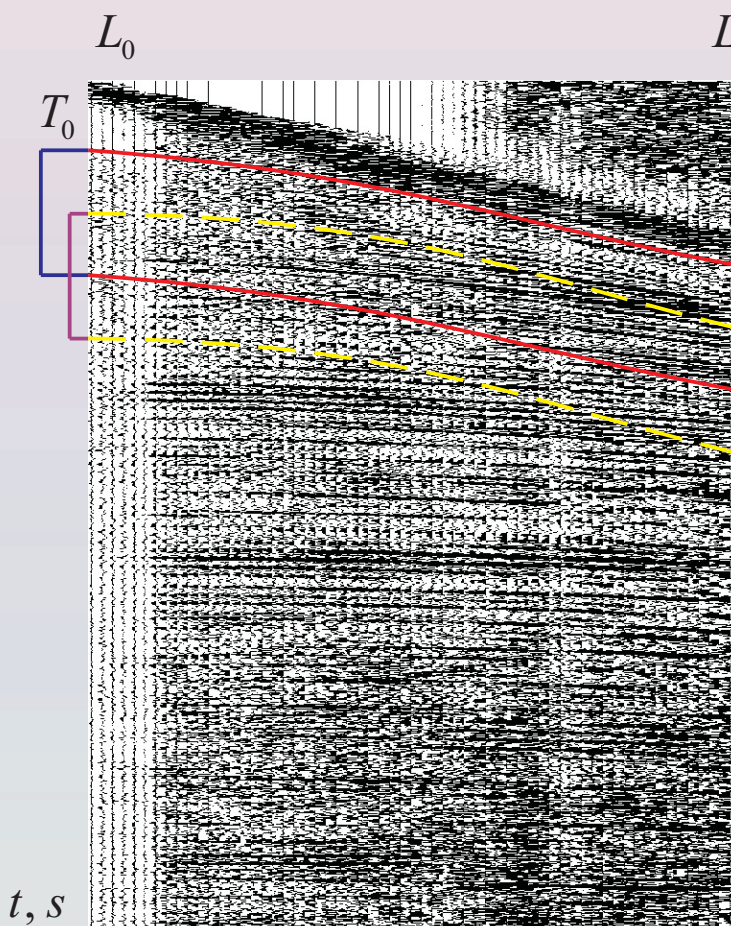
$$L \quad _0 e^{\quad _1 |L| \, |L_0| \quad _2 \quad |L| \, |L_0|}$$

$$T \quad _{T_0} e^{\quad _3 \, T \; T_0 \quad _4 \quad T \; T_0}$$

Autocorrelation calculation for prediction error operator

$$p \quad B \quad SP \quad RP \quad F_L \quad F_T$$

B — *basic autocorrelation,*
SP — *shot point factor,*
RP — *receiver point factor,*
F_L — *offset factor,*
F_T — *time factor*

HDS VELOCITIES
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True P, S velocity model from the surface
Controlled relation between static corrections and near surface velocity model
Истинная P, S скоростная модель от поверхности без линии приведения
Контролируемое распределение между статикой и приповерхностной скоростной моделью

CSP seismogram

Offset, m

Time, ms

Coherency

Hyperbolic parameter (ms / 1000 m)

Correlation
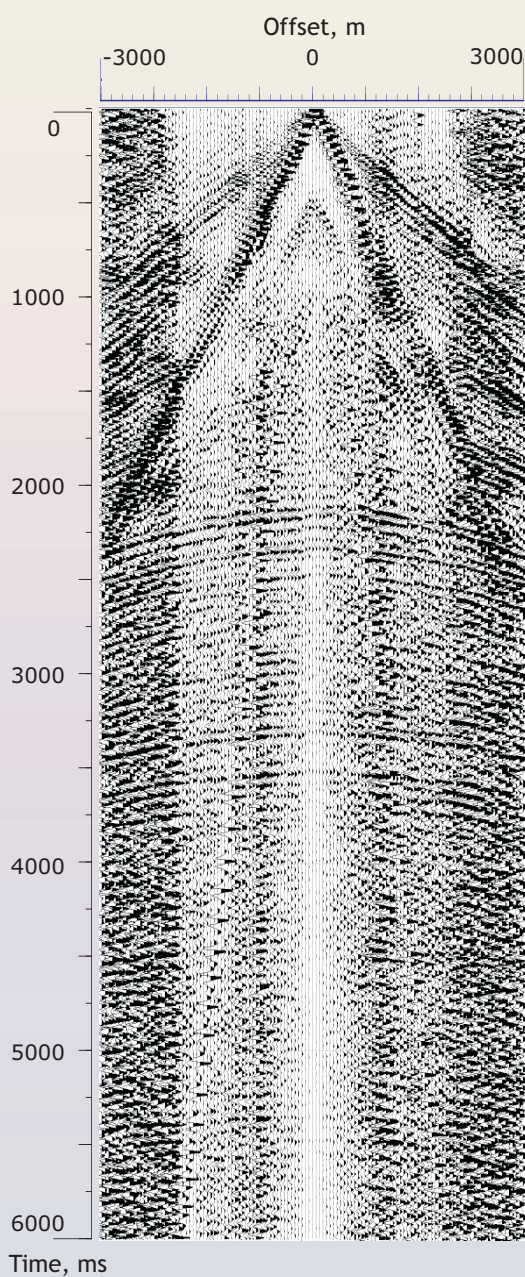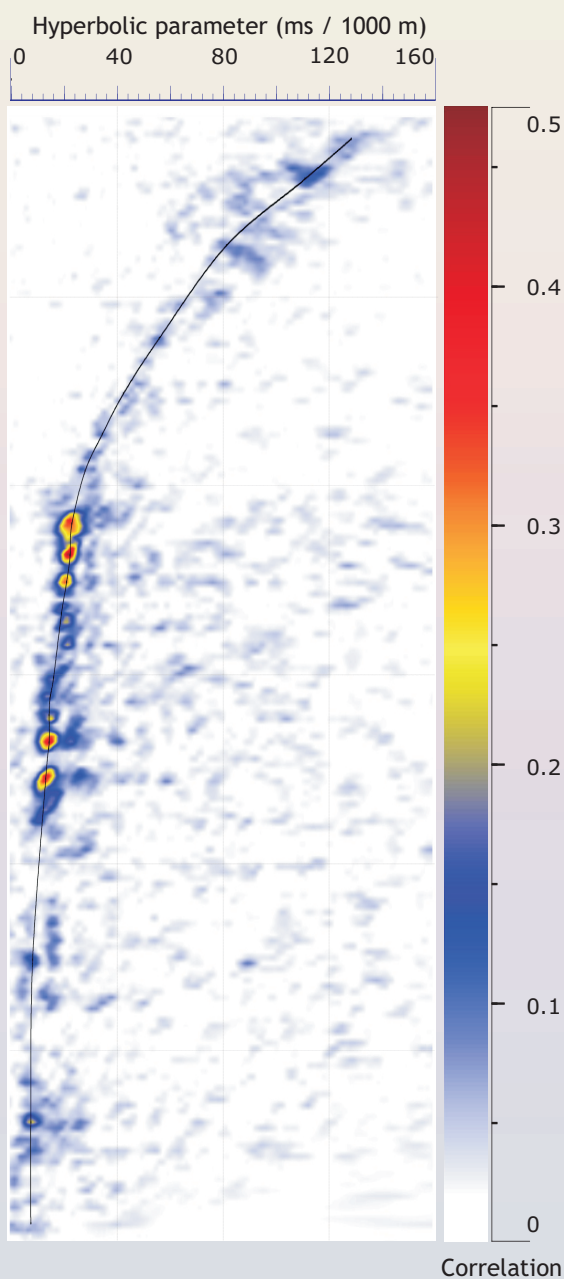
Polynomial approximation

K1

K2

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MIGRATION

Imaging through vector migration with true velocity model
Векторная миграция для построения изображений с использованием истиной скоростной модели
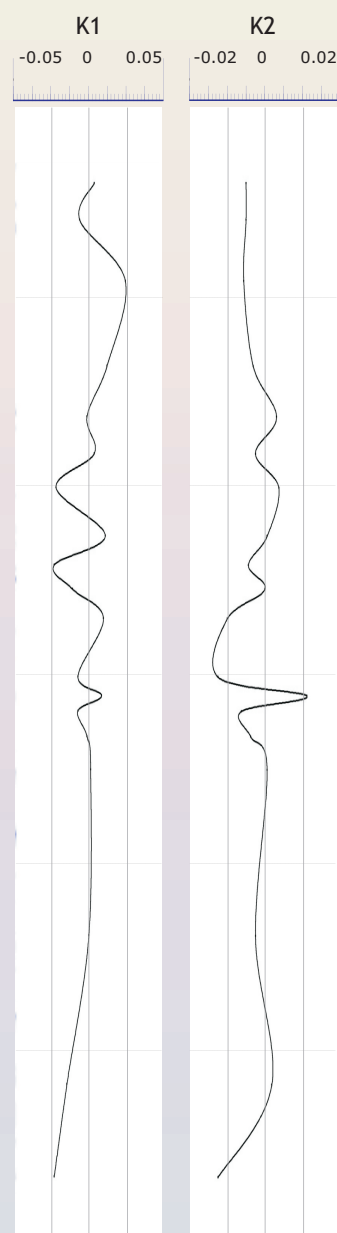
Main principles

> Finite difference 3D continuation of wave fields inside the medium

> 3C volume velocity separation of wave fields for every point of medium

> True normal reflectivity restoration with the use of PP and PS direct and dispersed waves

Synthetic example

Seismic image in terms of K_P

Shot point

Well with receivers

Reflection coefficient in the well

Normal incidence reflectivity section

Kirchhoff migration image

Vector migration image
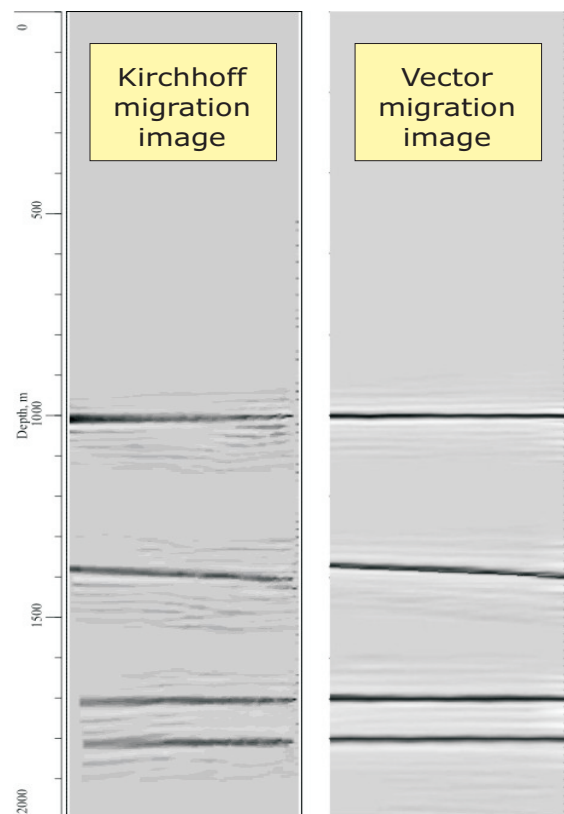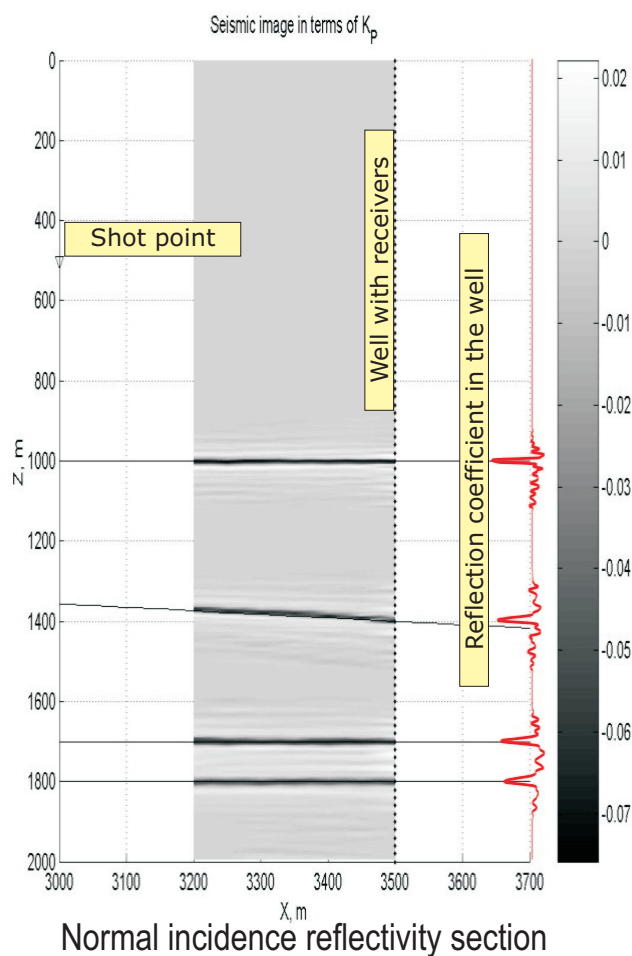
Reflectivity for normal incidence restored

HDS TECHNOLOGY
HIGH DEFINITION SEISMIC

Processing based on concept of artificial intelligence
Обработка основанная на подходах искусственного интеллекта

Intelligent approach to automatic separation of wavefields

Data   **Application**   **Experience**

Seismogram

List of appearances (waves):
reflections, raleigh, sound, direct, difracted, conversion, shear, etc.

Next one

Detection of the strongest appearance

Features of appearances

No ◄ Sufficient? ► **Yes**

Next iteration

Determination of parameters

Parameters of appearances. Methods of their determination

Residuals ◄ Transformation, Estimation, Subtraction ◄ Technological chains to work with appearances

Storage of appearances