E.Ye.Lukyanov, N.V.Belyakov

WAYS TO SOLVE GEONAVIGATION PROBLEMS BY GEOACOUSTIC METHODS WITH HORIZONTAL WELLS FIELD DEVELOPMENT

OAO GERS Research and Production Company
28/2, Chaikovsky Ave., Tver, 170034, Russian Federation
phone/fax: 7-0822-36-83-87
E-mail: trans@gers.ru

The paper presents ways to solve geonavigation problems by geoacoustic methods with horizontal wells field development, in particular by methods of interwell seismic survey while drilling with the use of special downhole ball vibrator and special systems of observations located in previously drilled wells. Obtained data is integrated with trajectory data obtained from bottom-hole telemetry system and data of mud logging while drilling.

Domestic and overseas experience of horizontal wells (HW) drilling reveals that in many cases constructed horizontal wells do not serve their special purpose, i.e. multiple increase of flow rate and extension of the water-free (gas-free) production period. The major reasons for it:

- horizontal borehole enters a zone of lithologic replacement or formation damage;
- horizontal borehole runs out of reservoir due to geologic reasons (tectonic destruction, barriers, etc.);
- horizontal borehole enters gas- or water-saturated part of the reservoir or approaches these zones closer than it is planned;
- other geologic reasons.

Certainly a series of horizontal wells is rejected for the reason of navigating operators' errors and imperfection of bottom telemetry systems and insufficient quantity of geophysical information, in particular – for lack of LWD-systems in the package. Still in many cases the major reason for the reject is the insufficient quantity of original geologic information.

Construction of a geological model from 2D seismic survey and logging data on the limited number of wells does not provide for the successful drilling of a horizontal well along the reservoir.

It is known from overseas experience that in many cases even such powerful technical and methodical means as LWD-systems, systems with steerable deflecting tool and reversed vertical seismic profiling with a bit operating at the bottom as a source of seismic signals do not solve the problem.

Let's consider ways to solve geonavigation problems with horizontal wells field development on the basis of combination of stationary and changeable geoacoustic systems of observation as well as through the use of efficient methods of studies while drilling.

Seismic survey while drilling can make the most substantial contribution to a pool model refinement, geonavigation accuracy enhancement and continuous field monitoring.

Seismic survey while drilling in the form of reversed vertical seismic profiling when a bit operating at the bottom serves as a source of seismic signals and receivers are located on the surface (by 4 traces as a rule) is performed in Russia [1] as well as overseas: "Tomex" technology of Western Atlas and "Seisbit" (SWD) technology of Eny Agip. These technologies though specious have the following essential drawbacks:

- the presence of a low-velocity zone in the upper part of the section that distorts operating bit's signals (it is of special importance in swamped land and with permafrost rocks in the section;
- a change of an initial signal on account of impossibility to keep steady drilling practices (load on bit, drilling bit rotations per minute etc.); different types of bits (tooth height, teeth number) and their wear while drilling;

- difficulty in geophones spread (geophone arrays) in swamped land (when a drill is mounted on the earth-fill foundation) in terms of spread operation and in terms of steady contact with the earth;
- inevitable interference of drilling equipment operation.

Here we are to add the fact that a mass change from percussion-shearing three-roller bits to more efficient bits with polycryctalline diamonds that use another mechanism of bottom destruction (cutting-scraping type) caused a sharp decrease of "Tomex" and "Seisbit" technologies application overseas as cutting-scraping type bits can't serve as sources of seismic signals with required properties.

A basically new technology of seismic survey while drilling is proposed:

1). A downhole ball vibrator is mounted in the BHA. The use of the vibrator as a source of seismic signals for the reversed vertical seismic profiling is demonstrated in [2].

Fig. 1,2 and 3 [2] show the properties of mud flow-operated downhole ball vibrators for vibrators of longitudinal (VPRK-170), transverse (VPK-170) and mixed (longitudinal-transverse VPPK-170) vibrations.

The difference is: a vibrator operates with non-rotating bit via which elastic vibrations are transmitted to the near-well zone by bit clamping to the bottom hole with 15-25 ton-force (depending on bit type and diameter). Under these conditions the vibrator starts to operate. With rotary drilling bit rotation shuts down by rotary switching-off and with mud motors drilling bit rotation shuts down by bypassing mud through the bypass channel (through the mud motor shaft as an example) that decreases greatly mud motor shaft's torque and causes the bit shut-down.

With this there's eliminated an interference of an operating bit and there are created conditions to control spectrum and energy of a transmitted signal that allows for better resolving power of the survey.

2). The second fundamental difference is deviation from the classical scheme of the reversed vertical seismic profiling when seismic vibration receivers (arrays of receivers) are located on the earth surface.

The object of geonavigation is the lower part of the section (producing formation as such and overlying rocks) so it is easier to receive signals in predrilled and cased holes. Using standard logging cable light seismic cables with 10-12 geophone arrays are run-in. They are safely fixed on the lower part of the casing at the time of measuring.

Prior to seismic cables running-in gyroscope measuring is mandatory performed to refine holes location.

3). Interwell seismic survey while drilling (MSI-PB) by new technology (Fig. 4) is performed every 5-12 m of a horizontal section drilling with accumulation of information for 3 – 5 minutes of the downhole vibrator operation on each measurement point. The best practice is to perform measurements every 8 – 12 m before or after pipe connection.

A change from the classical scheme of the reversed vertical seismic profiling to the technology of interwell seismic survey while drilling eliminates the drawbacks of the reversed vertical seismic profiling by the classical scheme (elimination of low-velocity zone, interference of an operating bit, difficulty in geophones spread in swamped land, interference of drilling equipment operation) and considerably enhances the obtained data quality.

Accumulated and preprocessed geophone signals are transmitted to the system of acquisition on the special program between radiation sessions. Keeping in mind that with the achievable accuracy of geophones location (by gyroscopic measurements) and of vibrations source location (by bottom telemetry) +/- 1 – 1.5 m one can examine heterogeneities of pool structure between a horizontal hole under drilling and holes of wells with seismic cables run-in (Fig. 4). The error will be the same.

Data obtained from geophones and bottom telemetry system via the system of data acquisition is input to a high-speed computer where it is processed with the use of special programs for 3D interwell constructions that are continuously refined after every operation of seismic vibrations source.

4). Interwell survey while drilling in the well cluster can be performed with computerized unit of geological and technological survey (mud logging unit) type of “SIRIUS” that is complemented by the equipment for seismic data processing and that receives signals from logging cables fastened at the head of wells whereto seismic cables are run-in.

The information obtained by the proposed technology does not have any drawbacks peculiar to the known technologies of seismic survey while drilling and enables to soundly correct a trajectory of a horizontal well under drilling so that to keep it within the most promising part of the formation by-passing lithologic wedging outs and other identified heterogeneities. It also enables to reliably project trajectories of subsequent horizontal wells in the cluster.

5). Parallel to the interwell seismic data obtaining with transmitter operating there are recorded reference signals at the transmitter as well as signals of geophones located at the BHA (option of positional acoustic logging with 8 -–10 m penetration depth to mark formation top-bottom position or gas-oil contact - water-oil contact). After the signals acquisition and preprocessing in the electronics package of the bottom telemetry system they are transmitted to the surface by the data link of the bottom telemetry system and are input to the common processing system thus complimenting data from seismic receivers located in previously drilled wells (Fig. 5, 6).

Proposed technology of the interwell seismic survey while drilling complemented by the capabilities of domestic LWD systems type of VIK-PB developed by NPP GA "“Luch" (the city of Novosibirsk); data links – being jointly developed by OAO NPP “GERS”, NPP GA "“Luch" and ZAO GIS-Pribor (Moscow), as well as complete use of software and methods of the computerized mud-logging unit of a new generation type of “SIRIUS” will solve geonavigation problems with horizontal wells field development on a new technical and methodical level that provides for considerable increase of horizontal wells drilling efficiency.

R E F E R E N C E S

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