P262 FULL-WAVE MODELLING OF EFFECTS CAUSED BY THE FLANKS OF SALT DOME

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Abstract

The large part of oil and gas fields in the Dnieper-Donetsk Basin (Ukraine) is belong to the salt domes of the Devonian and Permian age, which characterized by the complex tectonic framework and they are the reason of the major difficulties at the both 2D and 3D seismic data interpretation. Some of these problems can be resolved by the seismic data modelling based on acoustic/elastic wave equation.

In the given paper the example of full-wave modelling of effects caused by side parts of the typical krypto-diapir structure for the central part of the Dnieper-Donetsk Basin is considered.

Method

For modelling was used the realized on a standard PC the full-wave finite-difference scheme which allows the simulation of a time sections by the "exploding horizons" method (Claerbout, 1985), and also gives a possibility to generate the shot gathers on the basis of a solution of the acoustic or the elastic wave equation (Kostyukevich et al., 2000).

We use the following differential wave equation (continuous form), describing particle 2-D motion in velocity-stress terms:

Elastic case

(1) $$\frac{\partial g^x}{\partial t} = Q\frac{\partial f^x}{\partial x} + L\frac{\partial f^y}{\partial y};$$

(2) $$\frac{\partial g^y}{\partial t} = Q\frac{\partial f^y}{\partial y} + L\frac{\partial f^x}{\partial x};$$

(3) $$\frac{\partial g^s}{\partial t} = Q^s\left(\frac{\partial f^x}{\partial y} + \frac{\partial f^y}{\partial x}\right);$$

(4) $$\frac{\partial f^x}{\partial t} = P\left(\frac{\partial g^y}{\partial x} + \frac{\partial g^s}{\partial y}\right);$$

(5) $$\frac{\partial f^y}{\partial t} = P\left(\frac{\partial g^s}{\partial x} + \frac{\partial g^x}{\partial y}\right);$$

Acoustic case

(1) $$\frac{\partial g^x}{\partial t} = Q\frac{\partial f^x}{\partial x} + L\frac{\partial f^y}{\partial y};$$

(2) $$\frac{\partial g^y}{\partial t} = Q\frac{\partial f^y}{\partial y} + L\frac{\partial f^x}{\partial x};$$

(3) $$\frac{\partial f^x}{\partial t} = P\frac{\partial g}{\partial x};$$

(4) $$\frac{\partial f^y}{\partial t} = P\frac{\partial g}{\partial y};$$

where f^x, f^y – instantaneous particle velocities, g^x, g^y – normal stresses, g^s – shear stress,

$Q = \lambda + 2\mu = \rho\,\alpha^2$; $Q^S = \mu = \rho\,\beta^2$; $L = \lambda = Q - 2Q^S$; ρ = density; $P = \dfrac{1}{\rho}$;

α = compressional wave velocity; β = shear wave velocity.

The model is constructed by sequential drawing of seismic boundaries (top-down) with the help of the mouse on real seismic section, which can be used as a background with adjustable transparency. For all constructed thus geologic strata assign the acoustic parameters (propagation velocities of longitudinal and shear waves, and also density of rocks).

Results

The general view of an investigated oilfield is shown as a depth-scaled section of the migrated cube (Fig.1), built up with the help of the 3D pre-stack depth migration. In the central part of the image can see the salt dome of Devonian age.

Seismic investigations were executed with 3200 m maximum offset and with 24-fold spatial coverage (bin size 25x50 m). As it is visible from a Fig.1, the observations have the skips that are caused by a high-relief terrain, populated areas and developed network of the communications (roads and oil-pipelines). On the basis of this section the simplified (two-dimensional) model of a salt dome, which is shown in a Fig.2, was created.

The reflectors on the model were set up as interfaces between the macro-stratigraphical beddings. For creation of the model the velocity data from the available wells and also from the detailed depth-velocity information used at the pre-stack depth migration was involved.

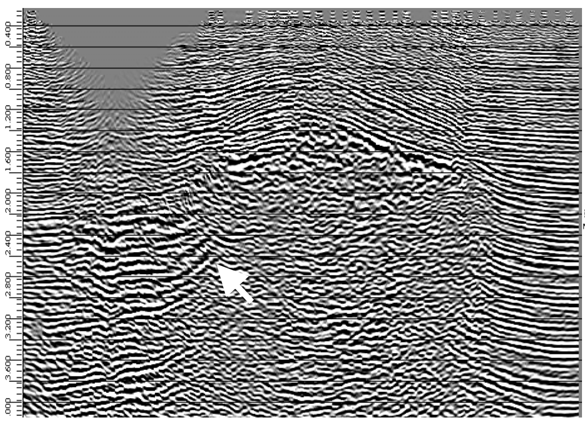

Fig. 1. The initial migrated sections in depth scale (arrow indicates prospective deposits)

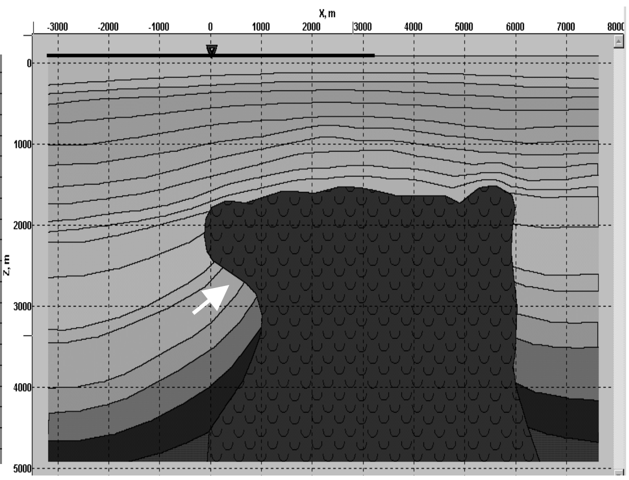

Fig. 2. Model of the salt dome (arrow indicates prospective deposits)

As it is visible from a Fig.2, one flank of salt dome has the eaves, and other is sub-vertical.

On the seismic image (Fig.1) and on the model (Fig.2) the arrows point to the productive objects in deposits of lower and middle Carbon, which located under eaves of salt dome.

For simulation of effects caused by the flanks of a salt dome, the method of “exploding horizons” was used (range of the incidence angles was from 0 up to 75^o). The signal frequency is 30 Hz. The modelling was fulfilled on a portable PC with the Pentium III-500 processor and RAM of 128 MB. Time section received as a result of full-wave acoustic simulation by a method of “exploding horizons” is shown in a Fig.3.

Then the model time section was processed with the help the full-wave finite-difference post-stack migration (Fig.4) with usage of the same velocity performances. In general it is possible to establish decent concurrence of the received seismic image to the model (Fig.2) except the abruptly pushed up parts of horizons under the salt cornice.

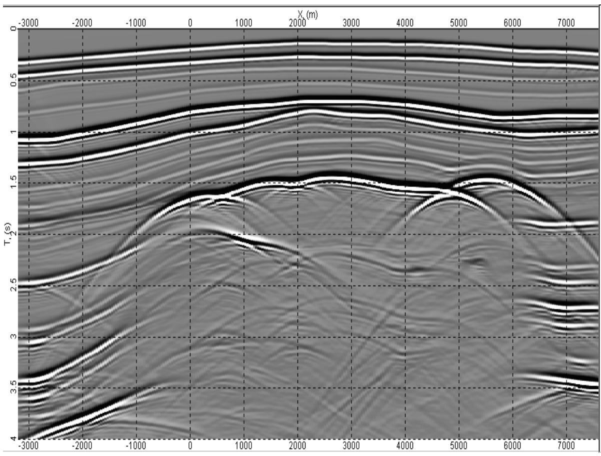

Fig.3. Time section received as a result of simulation

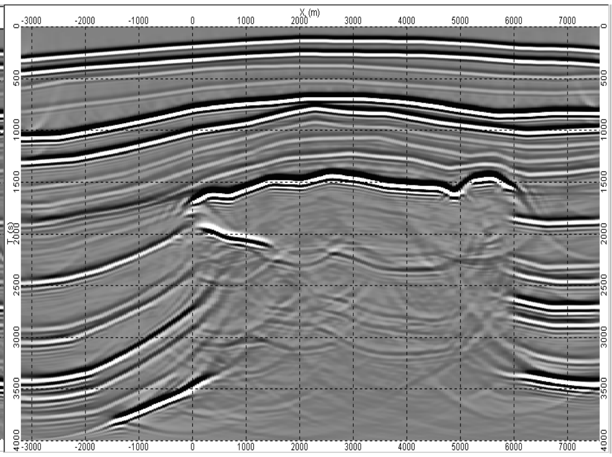

Fig.4. Post-stack migrated model section in time scale

With the purpose of detailing the process of a wave field passing through the salt stock eaves the serial of sequential instantaneous snapshots (Fig.5) was obtained. This snapshots give possibility to seen the distinct reflection from the eaves base (arrow on the last snapshot). For generation of snapshots the elastic modelling of the seismogram was used. The observation system have following parameters: symmetrical spread, minimum offset 40 m, maximum offset 3200 m, interval between receivers 40 m, sampling rate 2 msec.

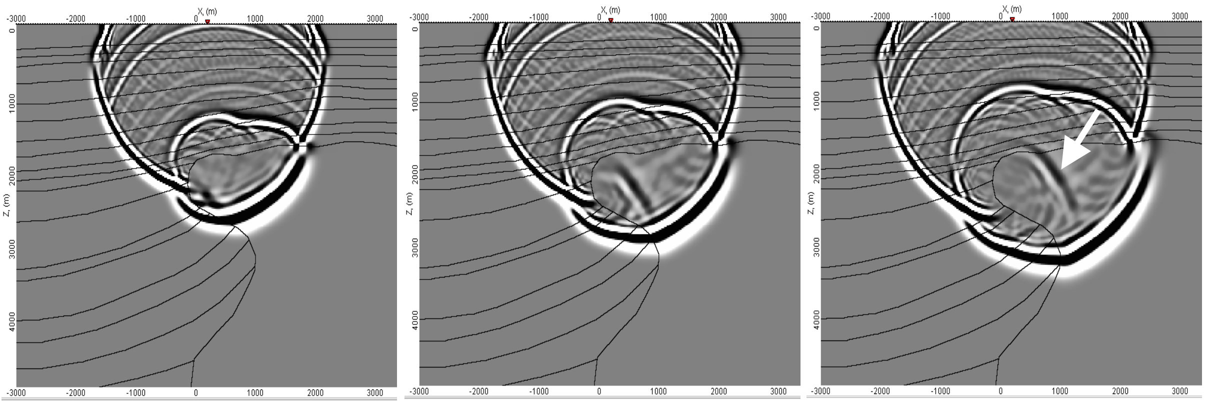

Fig.5. Sequence of the wave field snapshots. Arrow indicates the reflection from salt cornice

At further monitoring of the wave, reflected from a base surface of the salt eaves, it is possible to install a range of the source-receiver offsets, at which this wave goes out on a surface, and, thus, to calculate optimal length of the geophone spread.

On the basis of analysis of the received time sections (Fig.2-4) and the snapshots (Fig.5) it is possible to make the following conclusions:

1. Salt cover as the very contrasting acoustic boundary is dynamically brightly expressed in comparison with less sharp boundaries in terrigene deposits, as is supervised in practice.

2. In Pre-Mesozoic time the cap of a salt dome was eroded and represents rough surface from the acoustic point of view. Besides in the crest of a dome there is a detrital material, which was pushed up by salt from major depths (cap rock). Therefore this boundary in most cases is complicated by diffracted waves and time loops.
3. Base surface of the salt eaves is tracked rather confidently, as it is contrasting velocity boundary. On depths more than 3500 м the velocity of seismic waves propagation in terrigene deposits and in salt becomes practically identical, therefore sloping flanks of a salt dome not traced.
4. On a base surface of the salt eaves there takes place an inverse of seismic velocity, therefore this horizon is characterized by the phase inversion. This factor can be as the diagnostic sign of availability of the salt eaves. In this connection it is necessary carefully to apply routines of the waveform correction, for example, deconvolution, which can be reason of the loss of this important detail of the wave field.
5. Cap of the salt is a strong multiple-producing seismic boundary, from which supervised the trains of multiples and partial multiples. These waves can is erratic to be interpreted as sub-salt sediments. Therefore in conditions of krypto-diapir tectonics a mandatory procedure of the seismic data processing should be suppression of multiple waves.
6. The sub-vertical wall in a right side of a salt dome is tracked only with the help of ends of reflecting boundaries breached by salt, what is usually observed in practice.

More adequate result can be received at simulation of the shot gathers with the help of the full-wave equation, however while it requires very considerable computing time, and with use the following pre-stack depth migration.

Conclusions

The reviewed results of full wave modelling were used at interpretation of actual 3D seismic data on the West-Vilshany oilfield in Poltava area (Dnieper-Donetsk Basin, Ukraine).

In general the considered example confirm not only usefulness, but also necessity of the seismic data simulation for complicated media, in particular, for conditions of salt dome tectonics, using the increased possibilities of PC.

Acknowledgments

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