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Hydrocarbon fluid wave response from strata containing oil and/or gas associating with abnormal pore pressure above hydrostatic.

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Abstract: The observation of low frequency (2-4 Hz), low velocity (300 m/sec-400 m/sec so far noticed) and high amplitude over subsurface poro-fractured strata contains oil and gas is the main subject of our discussion (G.M. Goloshubin et al., 1993, Andika Perbawa et al.,2013 and G.K. Batta et al, 2014). The theory of seismic wave propagation cannot explain this phenomenon well enough. We developed a theory for possibility of hydrocarbon fluid wave which is responsible for low frequency, low velocity and high amplitude. Results of the theoretical research correspond to the data of field experiment.

Low frequency is due to natural oscillation of hydrocarbon fluids at poro-fractured strata. Low velocity is due to abnormal pore pressure above hydrostatic. High amplitude is due to resonance phenomena with natural oscillation of hydrocarbon fluids.

Utility of hydrocarbon fluid wave will confirm the hydrocarbon fluid presence in strata associating with abnormal high pore pressure gradient. It helps in prediction of depth, abnormal pore pressure above hydrostatic, Mud weight, Static Bottom Hole Pressure (SBHP) and average production rate per day.

Introduction

If seismic energy is subjected to subsurface porous rock, it spreads out as body waves and gets reflected, refracted, and transmitted. The main difference between water saturated rock and hydrocarbon saturated rock is low frequency-low velocity seismic observation. In this paper, we talk about shock wave interaction with natural oscillation of hydrocarbon fluids in poro-fractured strata associated with abnormal high pore pressure gradient results in resonant seismic emission of hydrocarbon fluid oscillations.

We think that the utility of the response of this wave will reduce hydrocarbon exploration risk and reduce risk of drill dry well in Oil Industry. We are with hydrocarbon fluid wave originating from poro-fractured strata contains oil and gas associating with abnormal pore pressure above hydrostatic.

Hydrocarbon fluid wave

Hydrocarbon fluid wave is a fluid generated low frequency (2-4 Hz) and low

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velocity seismic wave comes from the subsurface poro-fractured strata saturated with hydrocarbon fluids at abnormal high pressure zones.

Fundamentals in support of Hydrocarbon fluid wave

There are mainly two fundamental concepts that support Hydrocarbon fluid wave. They are,

1. Oil and gas are compressible fluids.
2. Abnormal pore pressure gradient

Our Proposed theory & Methodology

Any external source (example: Explosive of 2.5 kg to 5 kg in general used as seismic source) frequency or phase of shock wave fronts meet with natural frequency of vertical oscillations of oil and gas in poro-fractured strata, then, it oscillates or vibrate with maximum amplitude under resonance phenomenon. Then, the entire potential energy (abnormal pressure above hydrostatic) of fluid converts kinetic energy as per law of conservation of energy and it coupled with surrounding rock yields resonant behavior of wave response.

In active onshore conventional seismic data, the hyperbolic events with possible maximum amplitude are appearing at the late part of seismic records. Fluid oscillation spreads out low frequency low velocity hydrocarbon fluid wave (see Figure-01). In general, they are hidden in the seismic data as it contains many frequencies ranging from 1-70 Hz. To visualize these events, one can focus on its natural frequency (2-4 Hz) with some gain techniques.

However, all hyperbolic events in seismic record cannot be related to hydrocarbon fluid wave but the possible salient features of hyperbolic events concerned Hydrocarbon fluid wave are hereunder.

1. Occurs as late part of seismic record after all primary waves (P, PP Reflection, S waves etc) as hyperbolic events in conventional seismic data.
2. It must obey following **t^2 - x^2 equation as** it is one way wave front travelling from oil and gas at poro-fractured strata.

$$t^2 = t_n^2 + [2 / Vrms]^2 * x^2 \qquad (1)$$

Where t= travel time of hydrocarbon fluid wave at offset (X) (almost curve in shape)
t_n = Vertical or normal travel time of hydrocarbon fluid wave
X = distance from normal travel time sensed sensor. Vrms = Root mean square velocity.
Slope = $[2 / V_{rms}]^2$

$$Vrms = [(V_n^2 + V_h^2)/2]^{0.5}$$

V_n = normal velocity or velocity of hydrocarbon fluid wave, V_h = horizontal velocity,
$V_n = 1.414 * V_{rms}$ (as $V_h = V_n \cos 90^{\circ}$)=0

$$V_n = 1.414 * V_{rms} \qquad (2)$$

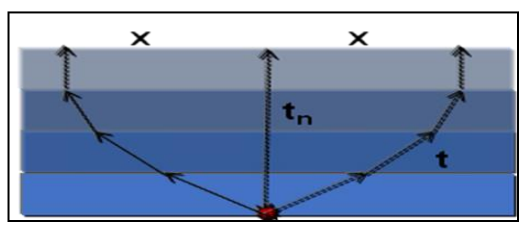

Figure-01. Schematic representation of Ray path from oscillation of Hydrocarbon fluid in poro-fractured strata

Concept of frequency hydrocarbon fluid wave

Basically, time period of any oscillator of mass (M), in the state of resonance is given by

or

$$\omega'' = \sqrt{(K/M)} \qquad (4)$$

Resonant frequency or natural frequency of unit mass ω" = √(K), where K = Restoring force constant that follows the force equation and responsible for harmonic motion.

As per oscillation theory in Physics, there is an expression of "Time period of oscillations of a frictionless piston of a cylinder filled with gas" and is given below.

$$T = 2\Pi \sqrt{(MV/ \Upsilon PA^2)} \quad (5)$$

where M is mass of gas, P is atmospheric pressure, ϒ is adiabatic constant, (C_P/C_V), A is cross sectional area of piston, V=volume of gas, C_P is specific heat of gas at constant pressure and C_V is specific heat of gas at constant volume.

From equation (1) and (2),

$$K= \Upsilon PA^2/V \quad (6)$$

The gas constant occurs in the ideal gas law, as follows

$$PV = nRT \quad (7)$$

Where P is the absolute pressure (SI units Pascal), V is the volume of gas (SI unit cubic meters), n is the chemical amount of gas (SI units mole), T is the thermodynamic temperature (SI units kelvin) and R is Universal gas constant (8.314 J/mol-K)

PV = RT (For unit mole and unit temperature) (8)

$$P = R/V \quad (9)$$

From equation (6) and (9),

$$K= \Upsilon R(A^2/V^2) \quad (10)$$

Therefore, restoring force constant for unit area, unit volume of ideal gas and unit or constant thermodynamic temperature is given below.

$$\mathbf{K= \Upsilon R} \quad \mathbf{(11)}$$

The restoring force constant of gases are varying from 11 to 13. For methane, it is 11. Resonant frequency (ω”) of methane per unit mass is square root of restoring force (K) constant for natural gas. Natural frequency of methane gas, ω" = √(K) = √11.1 = **3.33 Hz.**

As per oscillation theory in Physics, there is an expression of Time period of oscillations of a test tube filled with low dense liquid on water and is given below.

$$T = 2\Pi \sqrt{(m/ Adg)} \quad (12)$$

where d= density of liquid, A= radius of test tube.

From equation (3) and (12)

Restoring force constant of floating oil on water

$$K = Adg \quad (13)$$
$$= A(m/v)g$$

For unit area, unit volume and unit mass,

$$\mathbf{K= g} \quad \mathbf{(14)}$$

Free oscillations or natural oscillations of oil which float on water is mainly due to restoring force that equals to gravity. Natural frequency of oil which float on water is, i.e., √K = √g =√9.8= **3.13 Hz.**

Velocity of resonant hydrocarbon fluid wave

In general, rocks saturated with oil and gas have pore pressure above hydrostatic in the earth. We think that this natural available energy (pore pressure above hydrostatic) could be responsible for low velocity of hydrocarbon fluid wave (Figure-02).

The formula what we what we propose for Velocity (V) of Hydrocarbon fluid wave is (evolution of this formula has not been presented in this paper)

$$\mathbf{V = [2P /\rho Ø]^{1/2}} \quad \mathbf{(15)}$$

where P is abnormal pore fluid pressure (above hydrostatic) in Pascal, Ø is apparent porosity of rock (0 < Ø > 1) and ρ is average density of liquids available at rock fracture in earth's interior in kg/m^3 are being considered. The density of gas was ignored as it is very low in comparison with liquids like oil and brine water.

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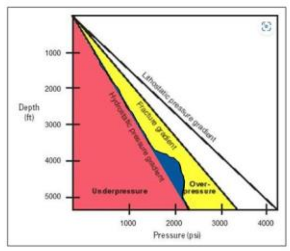

Figure-02: Pore pressure above hydrostatic: the pressure difference between pore pressure (curve in blue colour) and hydrostatic pressure (red line) is responsible for low velocity wave, if poro-fractured strata contain oil and gas between depth ranges 4000-5000 ft.

Future prospects of our proposed study

1. Confirms the presence of hydrocarbon fluid in poro-fractured strata associating with pore pressure above hydrostatic.
2. Could predict/estimate the depth with an accuracy range 90-95% as Shock wave travel time from seismic source to hydrocarbon fluid strata is very difficult to predict. It depends on many things like type of explosive used and charge size etc.
3. Estimation of the pore pressure above hydrostatic which helps in predicting Mud weight before drilling. Further, it helps in predict Static Bottom Hole Pressure (SBHP) at Reservoir level.
4. Evaluate the average production rate per day of crude oil, if any nearby well information like density of crude oil, effective porosity of rock, average production rate per day of crude oil and SBHP is available within the same structure.

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