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Seismic attribute for hydrocarbon expressions in stack section

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ABSTRACT

Stacking process in seismic data processing is a simple and powerful tool commonly used to remove undesired random noise and enhance signal to noise ratio. Basically, the process averages traces from prestack gathers (angles or CDPs) so that they present normal-incidence reflections in stack sections. Experience has showed that hydrocarbons-bearing sediments are generally characterized by anomalous amplitude changes relative to their background from an offset to another. This can result in interesting seismic expressions in the stack section that can help identify reservoirs and delineate their extensions.

This paper investigates the conceptual assumptions behind stacking and amplitude variation with offset (AVO). A new attribute is presented and used to detect and extract anomalies associated with hydrocarbon sand reservoirs from their background. The attribute has been examined on real datasets from different fields. The seismic-weighted instantaneous energy attribute showed excellent results in delineating bright spots associated with shallow gas accumulations as well as revealing stratigraphic features of two productive sand-filled channels. Indeed, the paper provides a new insight into seismic stack data analysis and interpretation.

1. Introduction

The assumption behind Amplitude Variation with Offset (AVO) concept is that the amplitude changes in the Common Depth Point (CDP) or angle gathers can be associated with the physical properties and pore fluid content of rock. Ordinarily, the amplitude change of CDP gathers is evaluated at a target interval. This evaluation yields information about the reflection coefficient at zero-offset (i.e. the intercept) and the rate of change with respect to the angle or offset (i.e. gradient). Typically, cross-plotting the two parameters can be done to differentiate the lithologies and fluid filling the pore space of formations. This technique has proved to be a successful hydrocarbon indicator and lithology discriminator in the Gulf of Mexico and in many sedimentary basins worldwide.

The standard seismic data processing flow involves transforming a set of CDP gathers into a stacked section. Conventional stacking relies on the fact that seismic traces after NMO corrections would be similar to a zero-offset or normal-incidence trace. Experience has proven that in the presence of hydrocarbons, the amplitude from hydrocarbon-bearing sediments would show amplitude changes from near to far offsets (Rutherford and Williams, 1989; Castagna et al., 1998). These changes of amplitude makes the stacking process assumptions do not hold. Rather, the process acts as an amplification process of the amplitude at gas-sand reflections and as an averaging or even attenuation process at intervals elsewhere. Thus, in the stacked section, one may encounter amplification, averaging, and attenuation along the time series of the same stacked trace. Therefore, the amplitudes from different traces at the same gather corresponding to different interfaces may not

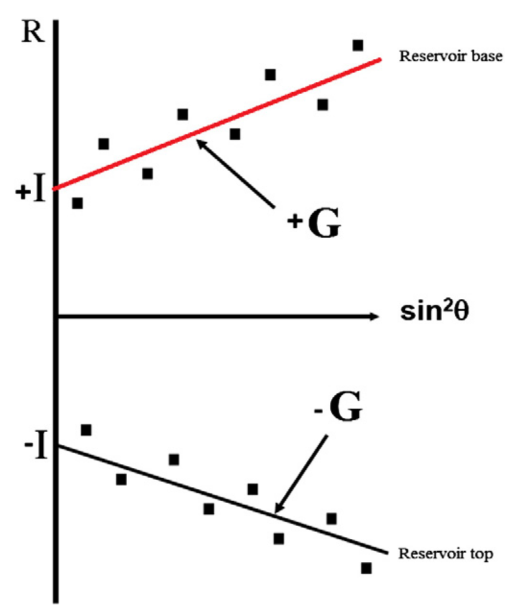

Fig. 1. Amplitude variation with square sine of the angle of incidence. The slope G represents the gradient and I is the intercept.

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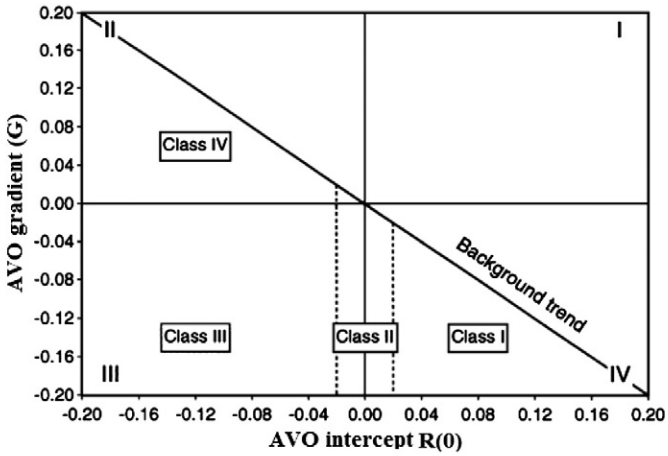

Fig. 2. AVO intercept (I) and Gradient (G) for different top gas sand reservoirs defined by Castagna et al. (1998).

be subject to equal conditions in generating seismic stack section traces. Consequently, stacked trace can differ from the zero-offset trace laterally (in the spatial direction) and vertically (in the time direction).

In this work, the seismic-weighted instantaneous energy attribute is presented. This attribute can assist in defining anomalous expressions associated with hydrocarbons and attenuate amplitudes elsewhere. The attribute was tested on a prestack and poststack 2D line from the Colony Gas field, East Central Alberta, and on a 3D dataset from Blackfoot field, Alberta, Canada. The attribute could clearly reveal the extension of the Colony gas sand anomaly and attenuate its surrounding formations. In the Blackfoot data set, the attribute successfully defined the thin glauconitic channel expressions and delivered its extension. Spectrally decomposing the attribute images helped delineate the hydrocarbon-bearing reservoir. Information from well data did support our interpretation and was consistent with our findings.

2. Stacking process and approximations of Zoeppritz equations

The Zoeppritz (1919) equations allow geophysicists to derive the exact plane wave amplitudes of a reflected P wave as a function of angle, but they do not give an intuitive understanding of how these amplitudes relate to the various physical parameters. Over the years, a number of approximations to these equations have been developed.

The first approximation of Zoeppritz equations was introduced by Bortfeld, 1961. His approximation for PP reflection amplitude is given by:

$$R(\theta) = \frac{1}{2} ln\left(\frac{\alpha_2 \rho_2 cos\theta_2}{\alpha_1 \rho_1 cos\theta_1}\right) + \left[2 + \frac{ln\frac{\rho_2}{\rho_1}}{ln\frac{\alpha_2}{\alpha_1} - ln\frac{\alpha_2 \beta_1}{\alpha_1 \beta_2}}\right] \frac{{\beta_1}^2 - {\beta_2}^2}{{\alpha_1}^2} sin^2\theta; \quad (1)$$

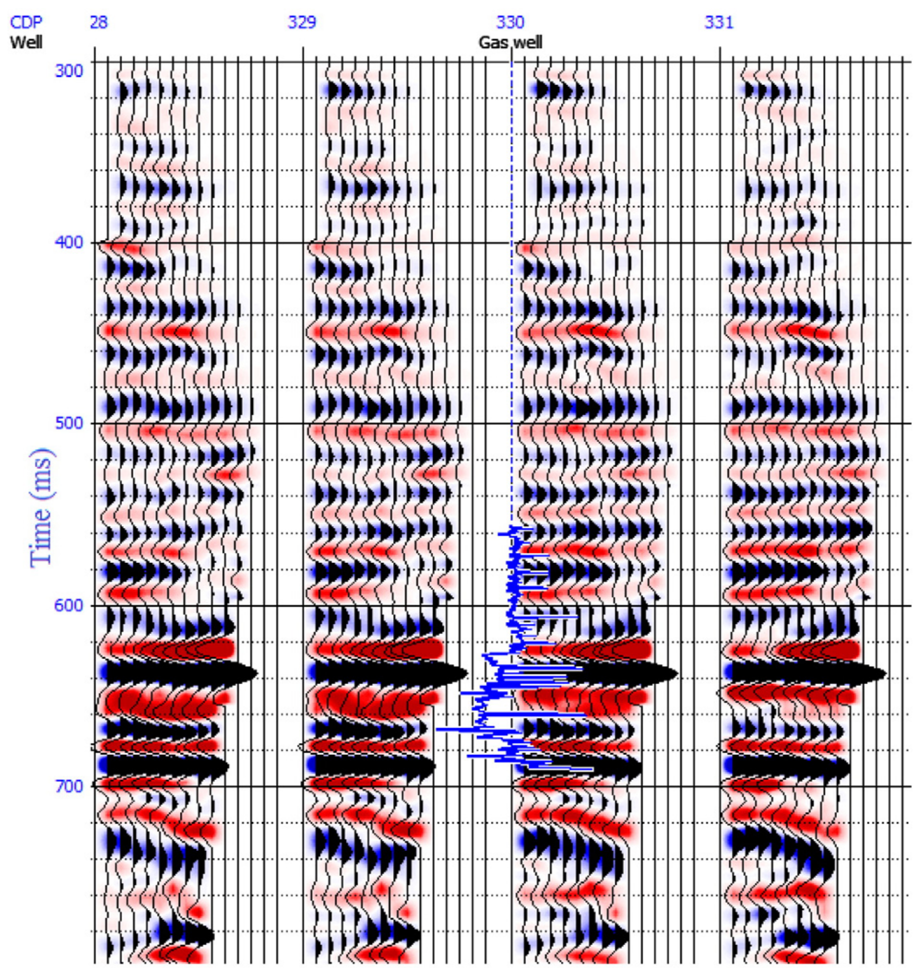

Fig. 3. Prestack data showing strong negative amplitude anomaly (red) at 625 ms. Red represents negative amplitude while blue with filled black peak represents positive amplitude. Note that color scale is normalized.