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Application Artificial Neural Network-Image Processing to Seismic Wave Propagation of Carbonate Rock

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Abstract: Seismic wave parameter plays very important role to characterize reservoir properties whereas pore parameter is one of the most important parameter of reservoir. Therefore, wave propagation phenomena in pore media is important to be studied. By referring this study, in-direct pore measurement method based on seismic wave propagation can be developed. Porosity play important role in reservoir, because the porosity can be as compartment of fluid. Many type of porosity like primary as well as secondary porosity. Carbonate rock consist many type of porosity, i.e., inter granular porosity, moldic porosity and also fracture porosity. The complexity of pore type in carbonate rocks make the wave propagation in these rocks is more complex than sand reservoir. We have studied numerically wave propagation in carbonate rock by finite difference modeling in time-space domain. The medium of wave propagation was modeled by base on the result of pattern recognition using artificial neural network. The image of thin slice of carbonate rock is then translated into the velocity matrix. Each mineral contents including pore of thin slice image are translated to velocity since mineral has unique velocity. After matrix velocity model has been developed, the seismic wave is propagated numerically in this model. The phenomena diffraction is clearly shown while wave propagates in this complex carbonate medium. The seismic wave is modeled in various frequencies. The result shows dispersive phenomena where high frequency wave tends to propagate in matrix instead pores. In the other hand, the low frequency waves tend to propagate through pore space even though the velocity of pore is very low. Therefore, this dispersive phenomena of seismic wave propagation can be the future indirect measurement technology for predicting the existence or intensity of pore space in reservoir rock. It will be very useful for the future reservoir characterization.

Key words: Carbonate, dispersive phenomena, rock physics, intensity, propagation

INTRODUCTION

Characterization of a hydrocarbon reservoir, that is delineation of the structure and description of the lithology and spatial variations in reservoir parameters is essential in oil-field development and production. Reservoir characterization has primarily relied on information from well data, generally obtained from only a few wells. Porous parameter plays important role in reservoir, especially for fluid reservoir. Several model of seismic wave propagation in porous zone, especially the effect of porous as well as pore's fluid to the velocity has been investigated by several authors (Biot, 1956a, b; Berryman, 1988; Batzle and Wang, 1992; Putri *et al*., 2015). In this study, we were show the effect of heterogeneity of carbonate in wave propagation, in various frequencies.

Literature review

Seismic wave propagation in pores: Some reseachers have investigated the effect of pores in seismic wave propagation (Biot, 1962; Gassmann, 1951; Gurevich *et al*., 2004). Biot (1962) has related the effect of frequency of seismic wave and pore's parameter by Eq. 1:

$$\omega_c = \frac{\mu\varphi}{k\rho_f} \qquad (1)$$

Where:
ω_c = Angular frequency
μ = The viscosity of fluid
k = Permeability of skeleton
ρ_f = The poroelastic coefficient of effective stress

In this study, we would like to show the effect pore's existence in seismic wave propagation's parameter. By

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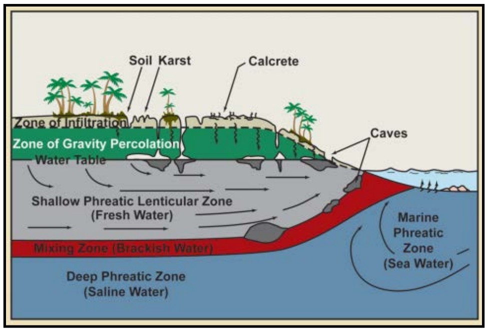

Fig. 1: Mechanism of generating digenetic pore system in carbonate (Scholle *et al.*, 2003)

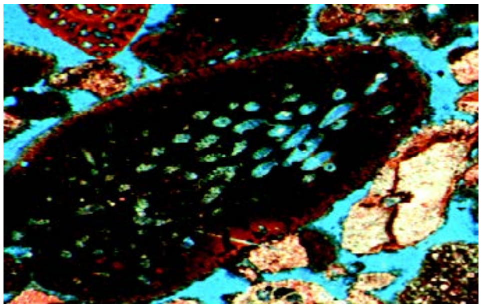

Fig. 2: Mouldic porosity

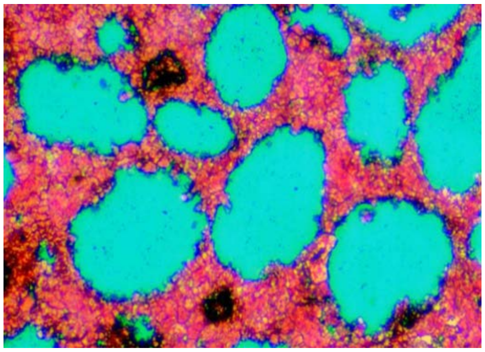

Fig. 3: Ooid porosity

numerical and Fresnel modeling of seismic wave propagation. Both of them for P-wave propagation without considering viscosity of fluid. And also permeability of skeleton.The input is just P-wave velocity of skeleton and pore including pore's fluid.

Pore type of carbonate rock: Carbonate rock has various types of pore, i.e., inter grain or inter crystal pore, moldic (intra fossil) pore and cavernous, fracture pore. See diagenetic pore in carbonate in Fig. 1, moldic porosity in Fig. 2 and ooid porosity in Fig. 3.

MATERIALS AND METHODS

Data analysis

Translating thin slice image into velocity using neural network: Neural network is one of computing procedure that imitate as close as possible with brain's working. Therefore the computation procedure imitate how the neuron working as shown by Fig. 4 and 5.

To model the wave propagation in carbonate rock, we use image from thin slice of carbonate rock. The carbonate rock was colored by blue dye for giving blue color in porous zone and then was dyed by alzherine to differentiate between dolomite and calcite.

This thin slice image is then trained by neural network using cell of neural network shown by Fig. 5. The training procedure is located in some positions as shown in Fig. 6. In these locations, the engine of neural network is trained to identify pore, dolomite and calcite. Pores are indicated by blue color, dolomite is indicated by red color and calcite is indicated by white color.

We were used multi-layer perceptron neural network (Carcione *et al.*, 2003; Zainuddin *et al.*, 2015) which output of prediction of neural network cell was formulated as following Eq. 2:

$$f_{MLP}(x) = \sigma\left(\sum_{k=1}^{n_h} w_k \sigma(w^{(k)}.x - \theta^k) - \theta\right) \tag{2}$$

Then, we had minimized the error of training sets by were minimizing Eq. 3 (Fig. 6):

$$E = -\frac{1}{2}\sum_{i=1}^{n}\sum_{i\neq j=1}^{n} w_{ij}x_i x_j - \sum_{i=1}^{n}\phi_i \tag{3}$$

Where:
w = Weight
x = Input
ϕ = True value in training object
θ = Bias
n_h = Number of hidden layer
σ = Sigmoidal activation function

Values of lithofacies prediction is resulted from neural network shown by Fig. 7 are then substituted by the velocity of dolomite, pore and calcite shown by Fig. 8 and 9.

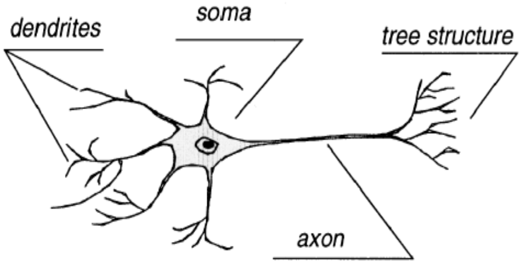

Fig. 4: Structure of neuron

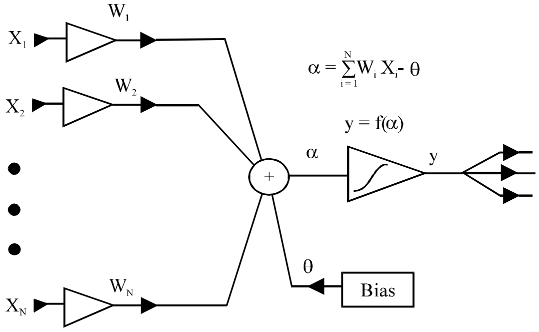

Fig. 5: Cell for neural network computation

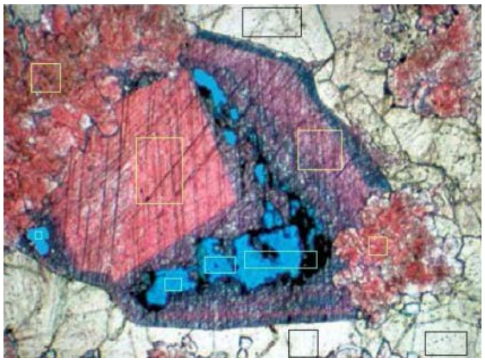

Fig. 6: Thin slice image of carbonate rock

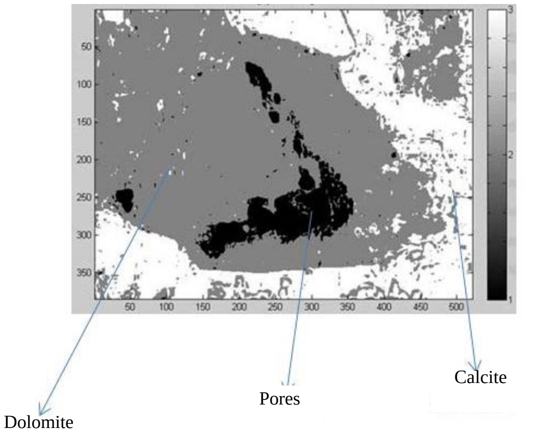

Fig. 7: Lithofacies prediction by neural network

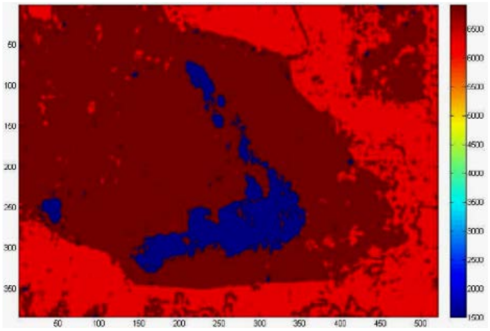

Fig. 8: Velocity matrix of carbonate rock

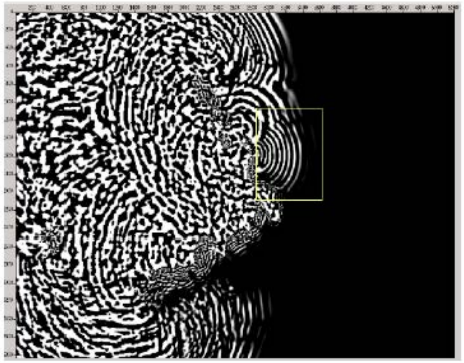

Fig. 9: Seismic wave propagation through model shown in Fig. 8

RESULTS AND DISCUSSION

Modeling of seismic wave propagation in carbonate rock: Some researchers studied the effect of porosity in seismic wave propagation (Carcione and Picotti, 2006; Dutta and Ode, 1979a, b; Silin and Goloshubin, 2010; Kelly *et al*., 1976) either based on Biot's theory and on Squirt's theory. In this study, we study about propagation of seismic wave phenomena in carbonate rock using various frequencies, the wave propagates elastic medium which contains pore's system.

Seismic wave modeling was used algorithm of Kelly *et al*. (1976) which simulate the seismic wave using finite differences. In this seismic wave propagation modeling considers P-wave only. It is clearly shown in Fig.10a and b, the amplitude of P-wave with high frequency (1000 Hz) is more attenuated in pore's space than the amplitude of P-wave with low frequency (100 Hz).

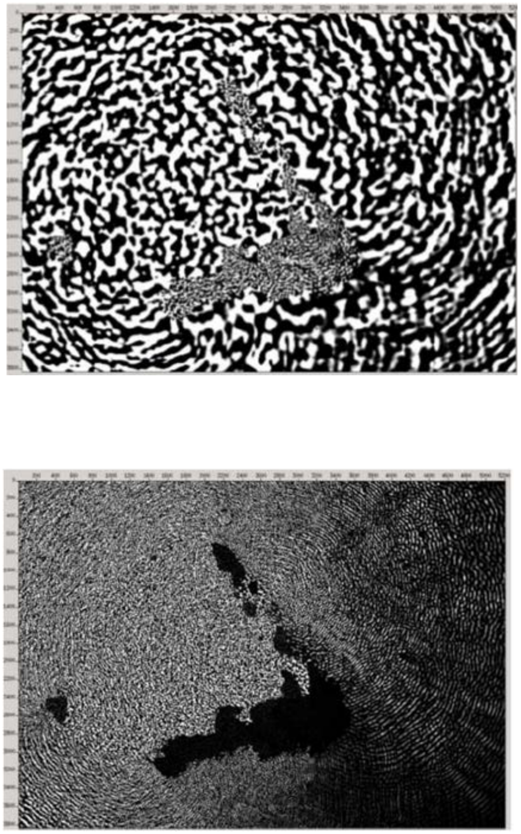

Fig. 10: Seismic wave modeling using various frequencies: a) modeling using 100 Hz; b) modeling using 1000 Hz

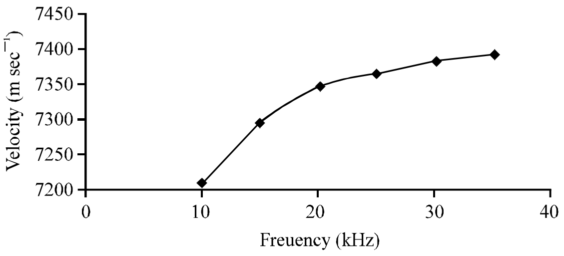

Fig. 11: Velocity wave modeling through velocity of Fig. 8 using various frequencies

The wave modeling is done also in various frequencies by positioned the source wave in left of velocity matrix and the receiver is located in the right side of velocity matrix, the velocities of seismic P-wave indicates dispersion phenomena as shown in Fig. 11.

CONCLUSION

Carbonate rock consist many type of porosity where the complexity of pore type in carbonate rocks plays important role in seismic wave propagation. High frequency waves provides higher attenuation in pore's space than low frequencies of seismic wave. Dispersive phenomena caused by the existences of pore can be observed clearly by seismic wave modeling. High frequency wave tends to propagate in matrix instead of pores. In the other hand, the low frequency waves tend to propagate through pore space even though the velocity of pore is very low.

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