Journal of Applied Geophysics 139 (2017) 223–238

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Seismic velocity deviation log: An effective method for evaluating spatial distribution of reservoir pore types

Mohamad Shirmohamadi [a], Ali Kadkhodaie [b,c,*], Hossain Rahimpour-Bonab [a], Mohammad Ali Faraji [a]

[a] Department of Geology, College of Science, University of Tehran, Tehran, Iran
[b] Department of Earth Science, Faculty of Natural Science, University of Tabriz, Iran
[c] Department of Petroleum Engineering, Curtin University, Perth, Western Australia, Australia

ARTICLE INFO

Article history:
Received 9 July 2016
Received in revised form 9 February 2017
Accepted 1 March 2017
Available online 06 March 2017

Keywords:
Pore type
Well logs
2D VDL section
Petrographic studies
Hendijan oilfield
Persian Gulf

ABSTRACT

Velocity deviation log (VDL) is a synthetic log used to determine pore types in reservoir rocks based on a combination of the sonic log with neutron-density logs. The current study proposes a two step approach to create a map of porosity and pore types by integrating the results of petrographic studies, well logs and seismic data. In the first step, velocity deviation log was created from the combination of the sonic log with the neutron-density log. The results allowed identifying negative, zero and positive deviations based on the created synthetic velocity log. Negative velocity deviations (below −500 m/s) indicate connected or interconnected pores and fractures, while positive deviations (above +500 m/s) are related to isolated pores. Zero deviations in the range of [−500 m/s, +500 m/s] are in good agreement with intercrystalline and microporosities. The results of petrographic studies were used to validate the main pore type derived from velocity deviation log. In the next step, velocity deviation log was estimated from seismic data by using a probabilistic neural network model. For this purpose, the inverted acoustic impedance along with the amplitude based seismic attributes were formulated to VDL.
The methodology is illustrated by performing a case study from the Hendijan oilfield, northwestern Persian Gulf. The results of this study show that integration of petrographic, well logs and seismic attributes is an instrumental way for understanding the spatial distribution of main reservoir pore types.
© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Carbonate reservoirs show higher complexity in comparison to their sandstone counterparts. This is due to their depositional heterogeneities inherited from lateral and vertical facies changes, which cause a complex pore type and size system (Wayne 2008). In addition, secondary diagenetic processes enhance these primary complexity and heterogeneity. Thus, one of the most important challenges in carbonate reservoir study is pore typing. Pore types determine the trend of permeability and using the velocity deviation log (VDL) can help petrophysicists to determine them from well logging data. Laboratory research shows that sonic wave velocity, in addition to volumes of porosity, depends on pore types. Velocity deviation log, as introduced by Anselmetti and Eberli (1999), is an important tool for pore typing of carbonate reservoirs.

Most productive Iranian petroleum reservoirs are carbonate reservoirs in which some diagenetic overprints such as compaction, anhydrite plugging, cementation and over dolomitization have reduced their quality during the geological time but fractures usually make them more prolific (Wayne 2008). These fractures generally play the main role in reservoir permeability increase and production.

In recent years an increasing trend for incorporation of seismic data into petrophysical investigations and interpretations is observed (e.g. Ouenes, 2000; Hampson et al., 2001; Doyen 2007, Kadkhodaie et al., 2009, Dezfoolian et al., 2013, Yarmohammadi, et al., 2014; Nouri-Taleghani et al., 2015; Nourafkan and Kadkhodaie, 2015; Kosari et al., 2015, Golsanami et al., 2015). Through inversion of amplitude based seismic data to acoustic impedance, many geological and petrophysical interpretations can be made. Acoustic impedance is highly under the influence of density and sonic compressional velocity, which are both related to rock properties.

The Hendijan oilfield (Fig. 1) is located 55 km west of Bahregan District, Persian Gulf. The Oligo-Miocene Asmari Formation is currently the main reservoir unit of the Hendijan oilfield. The mixed carbonate and siliciclastic interval of the Asmari Formation is characterized by a transgressive-regressive cycle formed under shallow marine and marine marginal/lagoonal waters in an overall regressive environment. The carbonate interval represents a westward extension of the productive Asmari Formation and the Ghar sandstone corresponds to the Ahwaz Member deposited in an onshore environment.

The current study reaps the benefits of both core and log data to generate a most reliable pore type log for the Asmari Formation at three wells of the studied field. Afterward, seismic data are inverted to acoustic

* Corresponding author at: Department of Earth Science, Faculty of Natural Science, University of Tabriz, Iran.
E-mail addresses: mshirmohamadi70@ut.ac.ir (M. Shirmohamadi), Kadkhodaie_ali@tabrizu.ac.ir, ali.kadkhodaie@curitn.edu.au (A. Kadkhodaie), hrahimpor@gmail.com (H. Rahimpour-Bonab), m.faraji@ut.ac.ir (M.A. Faraji).

http://dx.doi.org/10.1016/j.jappgeo.2017.03.001
0926-9851/© 2017 Elsevier B.V. All rights reserved.

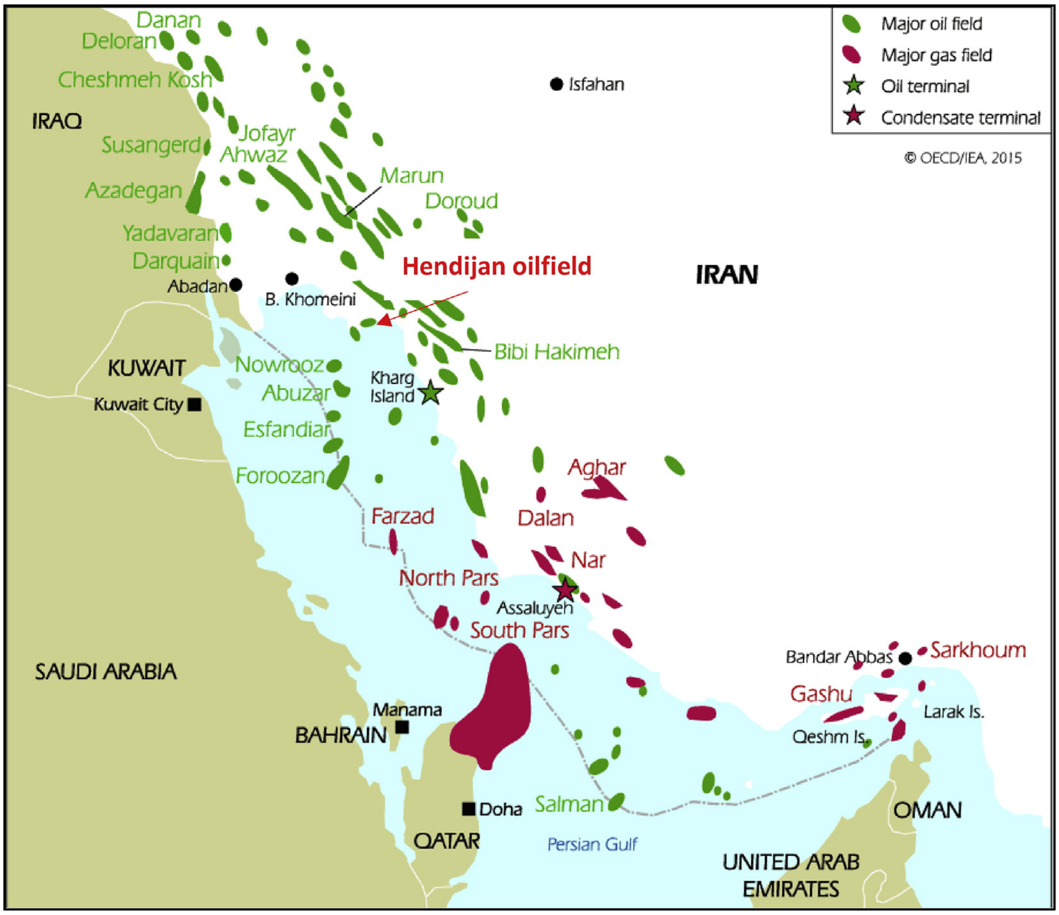

Fig. 1. Location map of the Hendijan oilfield in the Persian Gulf (IOOC reports, 2007).

impedance and then correlation models are established between inversion results and the most relevant seismic attributes by using probabilistic neural networks to generate a section of porosity and pore types.

It is worth mentioning that the neural network model for rock properties' estimation is not a novel topic and is mainly based on other researchers' work but it could be claimed that the current study is the first report of pore type determination from seismic data. The methodology is straightforward, robust and easy to implement.

2. Methodology

The current study proposes a two step approach to create a map of porosity and pore types by integrating the results of petrographic studies, well logs and seismic data in the Asmari reservoir. In the first step, velocity deviation log is created from the combination of the sonic log with the neutron and density logs. Then, the results of velocity deviation log are validated by using petrographic studies' results. In the next step, velocity deviation log is estimated from seismic data by using a probabilistic neural network model. For this purpose, intelligent formulations are made between inversion result (acoustic impedance) and the amplitude based seismic attributes.

Laboratory measurement on >300 samples reveals that sonic velocity in rocks in addition to porosity volume, highly depends on porosity types (Anselmetti and Eberli 1999). Actually, there is a negative correlation between porosity values and velocity. Frame-forming porosities (such as moldic or intra-fossil porosity), result in significantly higher velocity values at equal total porosities than porosities which are not embedded in a rigid rock frame, such as interparticle porosity or microporosity.

As defined by Anselmetti and Eberli (1999), velocity deviation log is defined as the difference between real and synthetic sonic velocity of rocks (Eq. 1).

$$\mathrm{VDL} = \left(\mathrm{Vp}-\mathrm{Vp}_{\mathrm{syn}}\right) \times 1000 \qquad (1)$$

where VDL is velocity deviation (m/s), Vp is compressional velocity (km/s) and $\mathrm{Vp}_{\mathrm{syn}}$ is synthetic compressional velocity (km/s).

Compressional and synthetic velocity are easily derived from sonic logs by using Eqs. (2) & (3)

$$\mathrm{Vp} = \frac{304.8}{\mathrm{DT}} \qquad (2)$$

$$\mathrm{Vp}_{\mathrm{syn}} = \frac{304.8}{\mathrm{DT}_{syn}} \qquad (3)$$

where DT is sonic log values in μs/ft. and 304.8 is a conversion factor to calculate Vp in km/s. $\mathrm{DT}_{\mathrm{syn}}$ in Eq. (3) refers to synthetic compressional velocity and is calculated mainly based on Wyllie's equation (Wyllie et al., 1956). The general form of Wyllie's equation is expressed as Eq. (4)

$$\mathrm{DT} = \mathrm{DT}_m(1-\varphi) + \varphi \mathrm{DT}_f \qquad (4)$$

where φ is porosity, DT refers to sonic wave travel time measured by logging tool, and DT_{m} and DT_{f} are sonic wave travel time in rock matrix and fluid occupied flushed zone, respectively. They were taken as 47, 55 and 189 μs/ft. for sandstone, limestone and flushed zone fluid respectively (Schlumberger, 2009).

Download English Version:

https://daneshyari.com/en/article/5787242

Download Persian Version:

https://daneshyari.com/article/5787242

Daneshyari.com