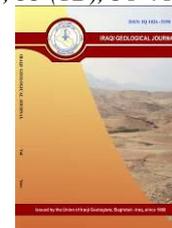




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New Equations to Determine Shear Velocity from Compressional Velocity in Hf-2 Well, Halfaya Oil Field

Ahmed Al-Banna^{1,*}, Hiba Tareq¹ and Ghazi Al-Sharaa²

¹ Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq

² Oil Exploration Company, Iraq

* Correspondence: geobanna1955@yahoo.com

Abstract

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The most important characters of the rock formations are shear and compression velocities, which are used to calculate elastic moduli. The geomechanical properties can be used to evaluate reservoir stability or to calibrate velocity and time/depth conversion, synthetic seismogram and other important applications. The aim of this study is to use the first order least square method to obtain an empirical equation to determine the shear velocity from compressional velocity for Mishrif, Rumaila, Ahmadi, and Mauddud formations in Hf-2 well. The obtained equations depend on sonic log and dipole shear sonic imager data of Hf-2 well and use Techlog software. The results from the obtained equations in comparison with those results of Green Castagna equation and measured data of dipole shear sonic imager of shear velocity for Mishrif, Rumaila and Mauddud formations. It is found from the comparison that the result is consistent each other's. The consistent reflect the reality of shear waves values obtained in these formations. The comparison in Ahmadi formation also shows a consistent result for the obtained equations but it shows some differences from the dipole shear sonic imager and shear velocity reference values. The authors believed that the difference in some values of the Ahmadi Formation may be due to the high shale volume in comparison to the other formations.

Keywords: Compressional velocity; Shear velocity; Halfaya Oil Field; Castagna Equation; First order least square method

1. Introduction

The well log data are very useful in processing stage of evaluation the geological formations. The importance of using shear velocity is ranging from seismic exploration, calculation of petrophysical properties and evaluation of the well stability. Sometimes not all logs are available, for example the dipole shear sonic imager (DSI) (Rezaee et al. 2006, Amunobereton-ari et al. 2010). The DSI have both monopole and dipole sonic acquisition abilities for the dependable acoustic measurement of compressional, shear, and Stoneley slowness's. The transmitter part is composed of a piezoelectric monopole transmitter and two electrodynamic dipole transmitters that are perpendicular to each other. In order to excite compressional- and shear-wave propagation in the formation; the electric pulse at sonic frequencies is used in the monopole transmitter (Al-Malikee and Al-Najim, 2018). In fact, this tool is not available in all wells mainly in old wells. When the direct measurements are absent; shear-

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wave velocity is usually estimated from P-wave velocity using empirical equations (Castagna et al., 1985, Greenberg and Castagna, 1992) or theoretical relationships (Krief et al., 1990, Eskandari et al., 2004, Brocher, 2005). These methods have some disadvantages and it can only be useful to give good results in regions where they can be determined. Other regions are in need for studying new relations which may be different from these equations by some amount depending on the geological conditions in the region. The dipole shear sonic imager for well (Hf-2) as one of the Halfaya oil fields located in the south of Iraq, which is used to calculate compression and shear velocities relationships for four carbonate formations from cretaceous age, which are Mishrif, Rumiala, Ahmadi and Mauddud formations, then calibrate these velocities to predict accurate equations compatible with Iraqi conditions. Halfaya oilfield was discovered in 1976 by well HF-1. The Well HF002-N004 was proposed as a horizontal development well to test the hydrocarbon potential in Halfaya area, the structure was defined by 2D seismic data between 1974 and 1980; up to 2009, seven wells have been drilled and significant oil accumulations have been discovered in the Tertiary Jeribe, Euphrates, Upper Kirkuk formations and the Cretaceous Sadi, Tanuma, Khasib, Mishrif, Nahr Umr, and Yamama formation (M.O.C., 2012).

There are several previous studies which used different methods to calculate shear velocity (V_s) from compressional velocity (V_p). Opiriyabo et al. (2014) calculated V_s from V_p using Greenberg and Castagna (1992) equation for AK-1 and AK-2 wells in the Niger Delta Basin of Nigeria; the results of this study showed that V_p and V_s increased with depth for all sand and shale lithologies while V_s was larger in shale compared to sand formations. They plotted a linear trend for each type of velocity with depth as well as a linear trend relation between V_p and V_s . Adjei et al. (2020) studied the Tano North Field located in southwestern part of Gulf of Guinea, they calculated the shear wave velocity from the compressional velocity by using four different methods to estimate the shear wave velocity under three different conditions. The final results were estimated depending on obtained coefficient of determination and average absolute percent relative error between real and predicted values of shear wave velocity. Majeed and Alhaleem (2020) used a statistical method in which regression analysis equations were employed to predict shear wave velocities from well logs of a productive carbonate (limestone) of Mishrif Formation in Amara oil field southeast of Iraq; this method can estimate shear wave velocity in carbonate rocks with a correlation coefficient of close to unity. The aim of this study is to use the first order least square method to obtain an empirical equation to determine the V_s , V_p for Mishrif, Rumiala, Ahmadi, and Mauddud formations in Hf-2 well.

2. Location of the Study Area

Halfaya oil field is located in Messan Governorate, southern of Iraq; it is located about 35 km southeast Amara City (Fig.1). The well HF002 almost is located on the anticline of the structure crest, 2.1 km to the north of the well HF-8 and 0.68 km northwest to the well HF-005 (M.O.C, 2012).

3. Stratigraphic Section of Hf-2

Halfaya Oilfield is a gentle elongated anticline, about 38 km long and 12 km wide, trending NW-SE to NWW-SEE. Formations penetrated by wells in Halfaya Oilfield include Cretaceous and Tertiary strata deposited in marine environment (Fig.2). In Halfaya area there are 4 major regional unconformable surfaces, namely tops of Shuaiba, Mauddud, Mishrif and Aaliji. The mishrif Formation consists mainly of limestone and grainstone while the major structure of Rumaila Formation is dense limestone with some argillaceous component, and Ahmadi Formation mainly consists of claystone interbedded with limestone and lastly the chalky limestone constitutes the main part of Mauddud Formation. (M.O.C., 2012) (Aqrawi et al. 2010).

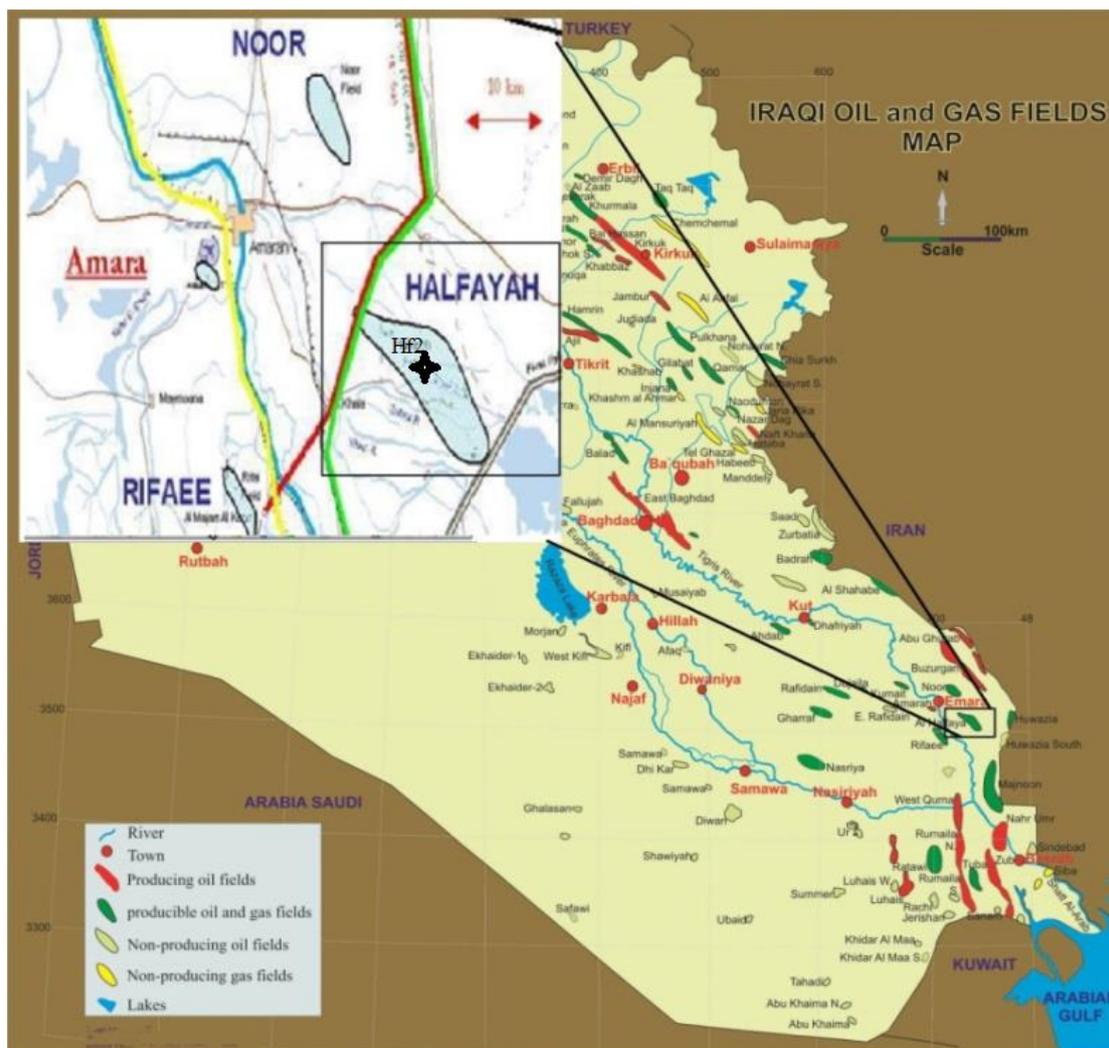


Fig.1. Location map of the study area (Al-Khafaji et al. 2013)

4. Materials and Methods

The presence of each type of sound velocities values in the logs set for any exploration well is very important because they are considered as keys for calculating Poisson ratio and lithology type and many other different physical properties. The available well log data are the V_p and V_s values of Hf-2 well. The data of Mishrif, Rumaila, Ahmadi and Mauddud formations of cretaceous age were used to obtain a regression relationship between V_p and V_s for these formations. Regression define as a statistical method used to determine the relation between two variables on of them is known and generally represented in x axes and the other unknown represented in y axes, there are three types of regression are linear regression, multiple linear regression and non-linear regression methods (Gallo, 2015). The second aim is comparing the results of the determined relationship with the equation of Greenberg and Castagna (1992). The Greenberg and Castagna depends on determination of V_s from V_p using three equations (1, 2 and 3) for different lithologies (Greenberg and Castagna, 1992). The Castagna equations are

$$V_s = -0.05508 V_p^2 + 1.01677 V_p - 1.03049 \text{ (Limestone)} \quad (1)$$

$$V_s = 0.8042 V_p - 0.5588 \text{ (Sandstone)} \quad (2)$$

$$V_s = 0.76969 - 0.86735 \text{ (Shale)} \quad (3)$$

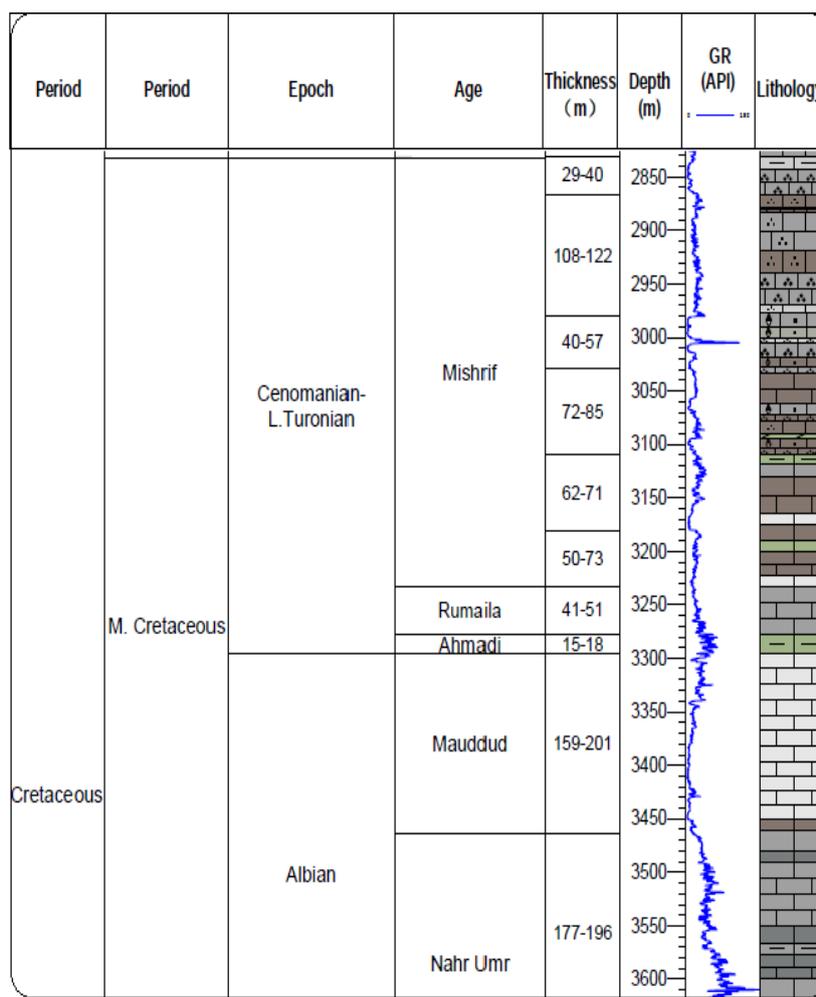


Fig.2. Stratigraphic section of the Halfaya oil field Hf-2 (M.O.C, 2013)

5. Results and Discussion

The empirical relationship equations between the V_p and the V_s were determined using first order least square fitting for Mishrif, Rumaila, Ahmadi and Mauddud formations in Hf -2 well, (Figs. 3, 4, 5, 6 and 7). The obtained equations and their regressions were tabulated in Table1. Figs. 8, 9, 10 and 11 show the final computer interpretation for this study as the first column reflects compressional transit time of DT in pink V_p in purple color line, the second column reflects V_s measured by four methods while the red line represents shear velocity which is calculated from formation predicted equation; the pink line represents shear velocity which is calculated from general predicted equation for all four formations in the well of Hf-2; the green line represents the shear velocity that is measured from well DSI log which exists in this well and is read from field directly and is considered as a reference to calibrate all other three shear velocities. Finally, the blue line represents shear velocity measured using empirical Greenberg -Castagna equation using Techlog 2015 software. The third column reflects the shale volume that is calculated using gamma ray log. The results from these figures indicate that all three shear velocities measured from spatial formation equation, all formation equation and Greenberg -Castagna equation are consistent and very close to the DSI shear velocity line in the Mishrif Formation as seen in Fig.8; in the Rumiala Formation they are close to the reference shear velocity (Fig.9), in the Mauddud Formation, they are close to each other but the shear velocity that is measured from formation equation is nearest to the reference shear velocity as shown in Fig.11; in the Ahmadi Formation, the three measured velocities are consistent but there are differences between them and DSI V_s which may

be caused by the high percentage of shale volume in this formation and high porosities compared with other formations We can suggest that the predicted equation in this study can be used to calculate Vs from Vp in the Mishrif, Rumiala and Mauddud formations in the Halfaya oilfield.

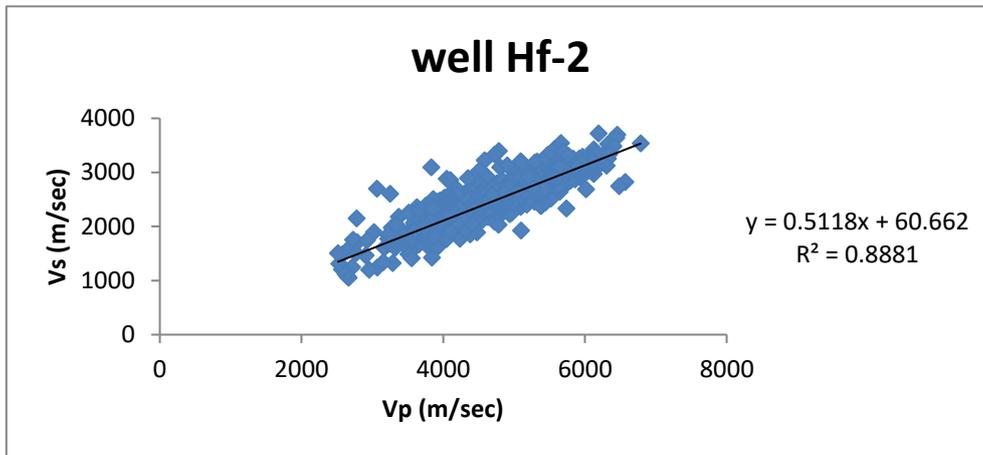


Fig.3.The Vp and Vs relationship obtained from actual field sonic log data at Halfaya oil field. Where y represents the y axes Vs, x represents x axes Vp and R is regression

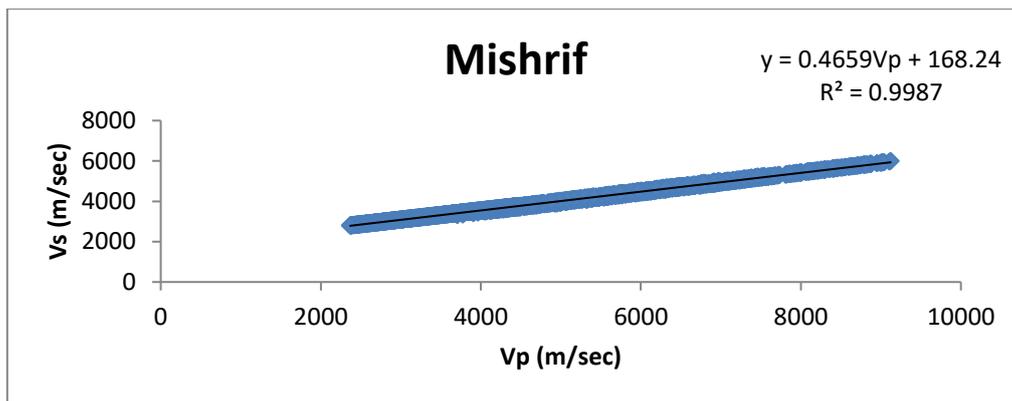


Fig.4.The Vp and Vs relationship obtained from actual field sonic log data for Mishrif Formation at Halfaya oil field

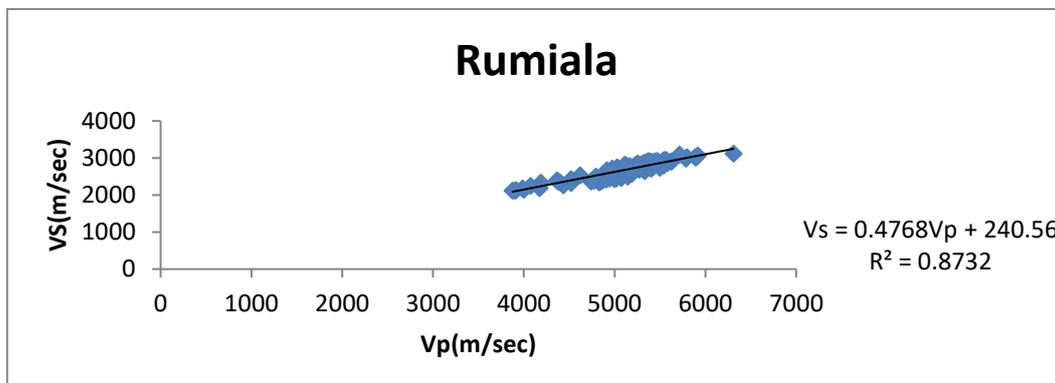


Fig.5.The Vp and Vs relationship obtained from actual field sonic log data for Rumiala Formation at Halfaya oil field south of Iraq

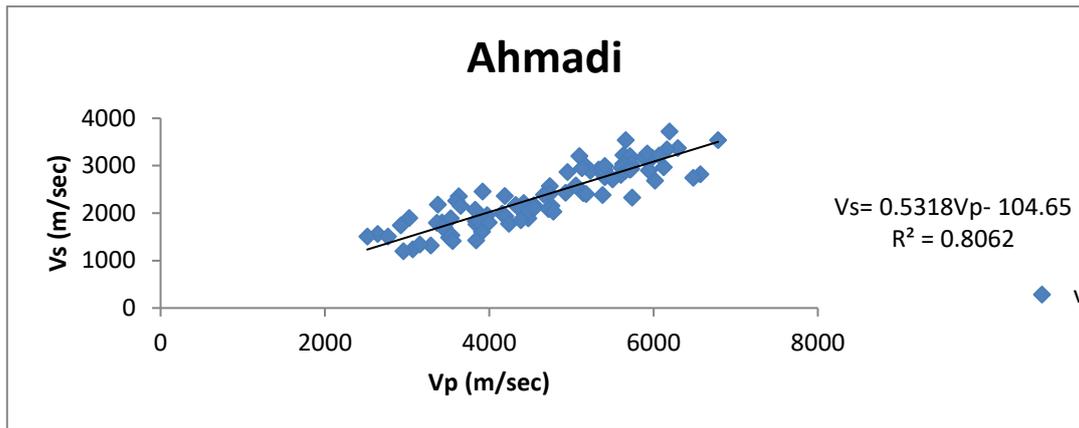


Fig.6.The Vp and Vs relationship obtained from actual field sonic log data for Ahmadi Formation at Halfaya oil field. From this relation we conclude that the existing of high shale volume in this formation cause diffraction in the points and reduce the regression value

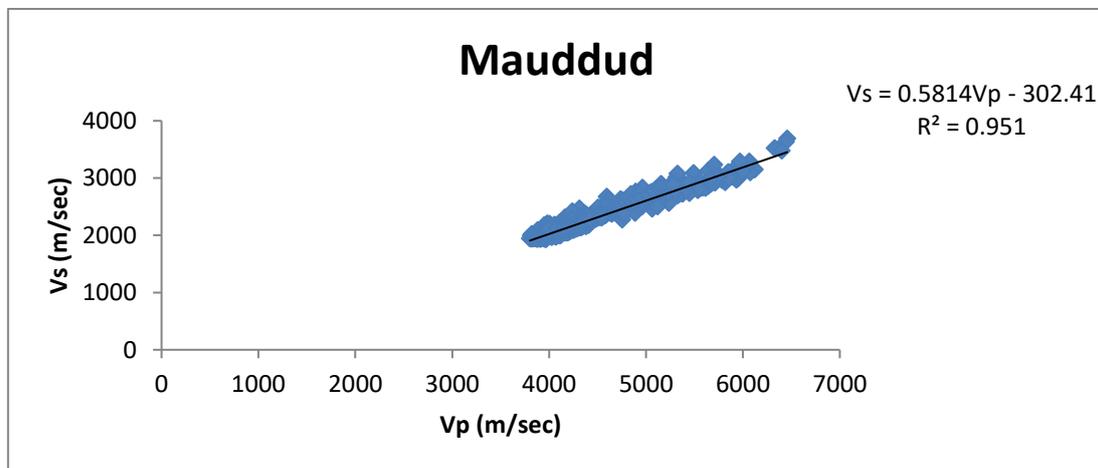


Fig.7.The Vp and Vs relationship obtained from actual field sonic log data for Mauddud Formation at Halfaya oil field

Table1. The equation that is derived for each formation and General equation the well of Hf-2

Formation	Equation	Regression	General equation	Regression
Mishrif	$V_s=0.4659V_p+168.24$	0.9987	$V_s=0.5118V_p+60.662$	0.8881
Rumiala	$V_s=0.4768V_p+240.56$	0.8732	$V_s=0.5118V_p+60.662$	0.8881
Ahmadi	$V_s=0.5318V_p-104.65$	0.8062	$V_s=0.5118V_p+60.662$	0.8881
Mauddud	$V_s=0.5814V_p-302.41$	0.951	$V_s=0.5118V_p+60.662$	0.8881

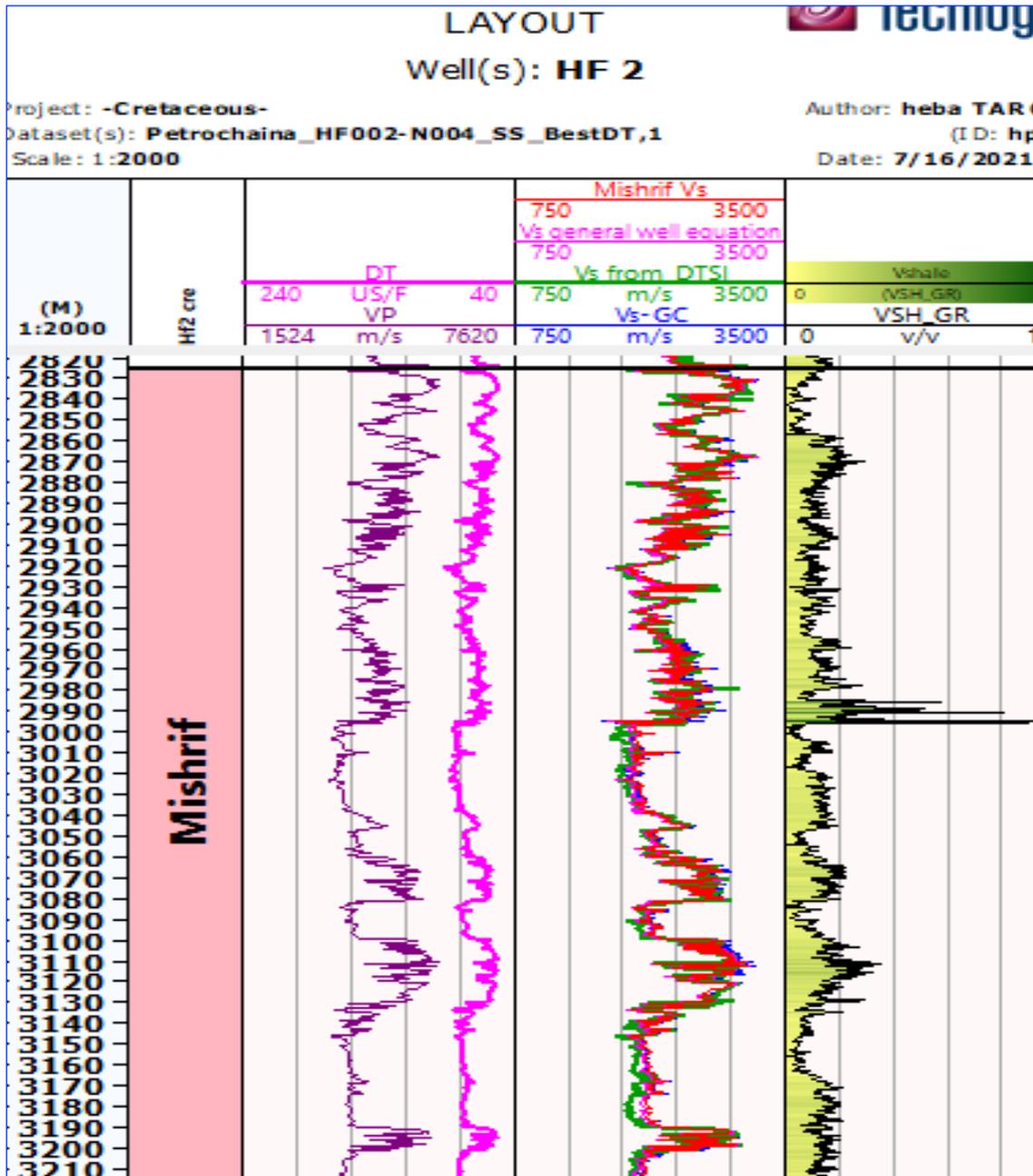


Fig.8. The CPI image represents the distribution of compression wave and shear wave velocities with depth of Mishrif Formation. The general equation obtained for Hf-2 well (pink), spatial formation equation Vs (red), DSI Vs that reflects velocity measured from dipole shear sonic log and Greenberg and Castagna equation (blue)

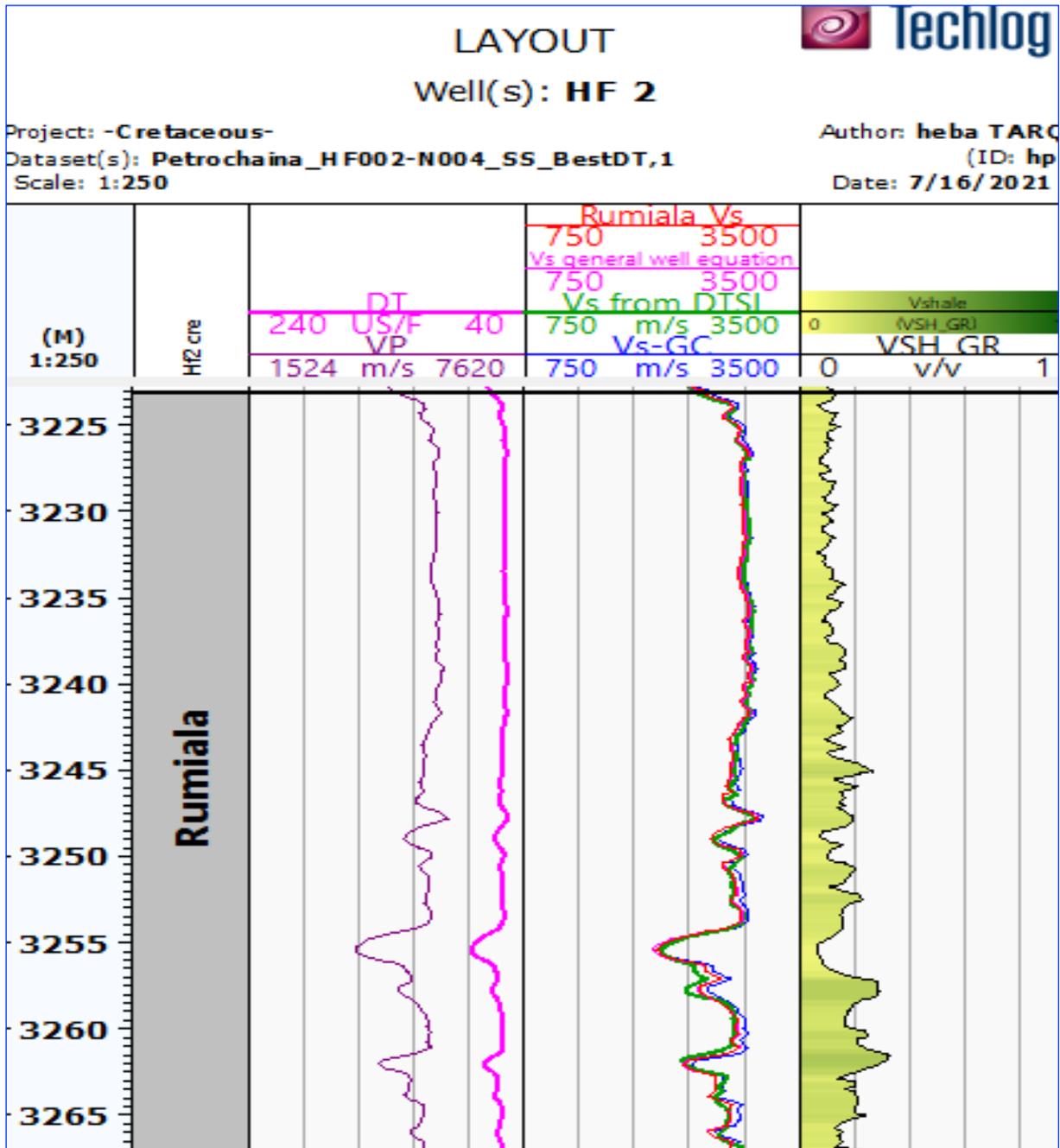


Fig.9.The CPI image represents the distribution of compression wave and shear wave velocities with depth for Rumiala formation. The general equation obtained for Hf-2 well (pink), spatial formation equation Vs (red), DSI Vs that reflects velocity measured from dipole shear sonic log and Greenberg and Castagna equation (blue)

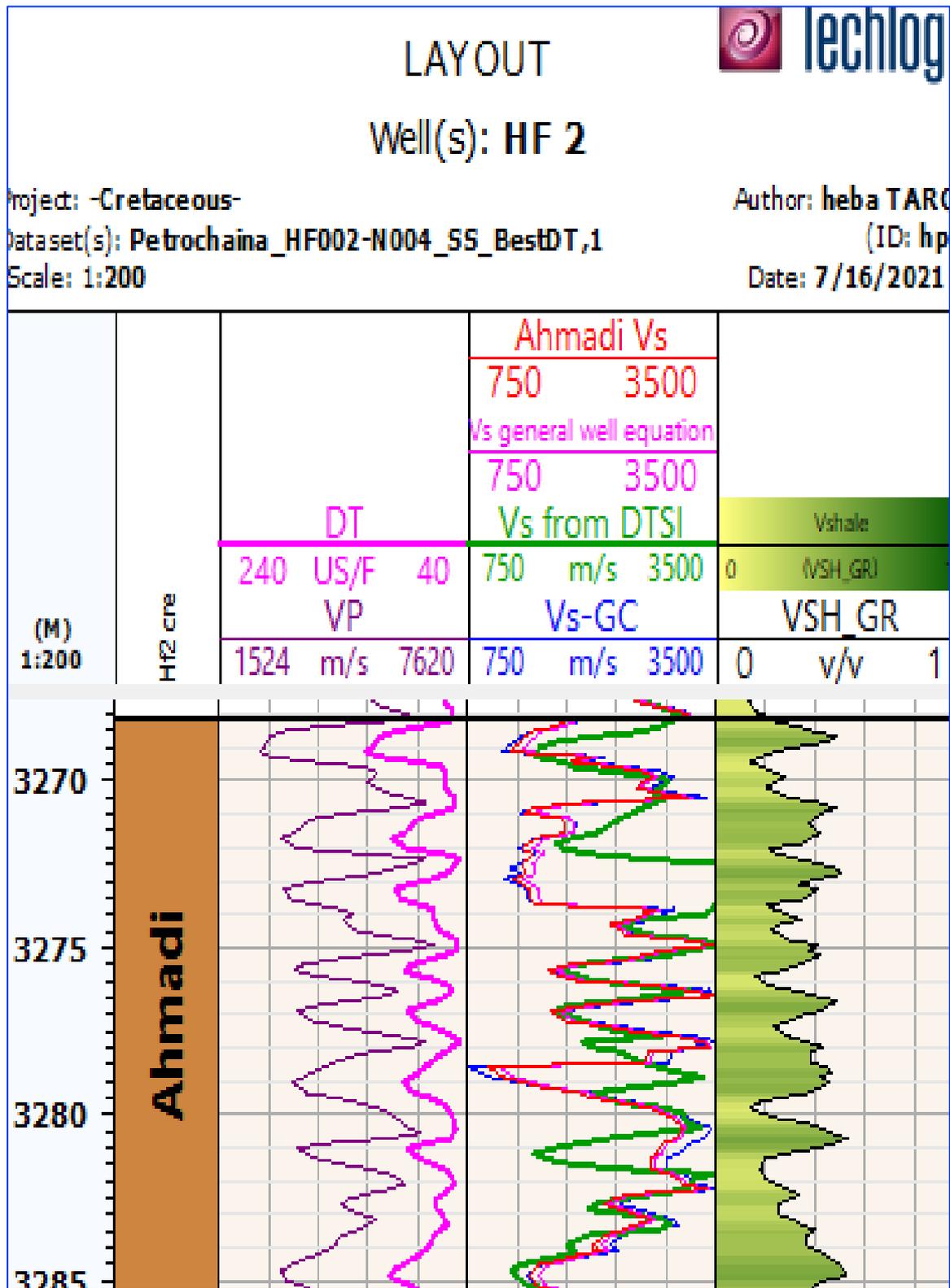


Fig.10.The CPI image represents the distribution of compression wave and shear wave velocities with depth of Ahmadi formation. The general equation obtained for Hf-2 well (pink), spatial formation equation Vs (red), DSI Vs that reflects velocity measured from dipole shear sonic log and Greenberg and Castagna equation (blue)

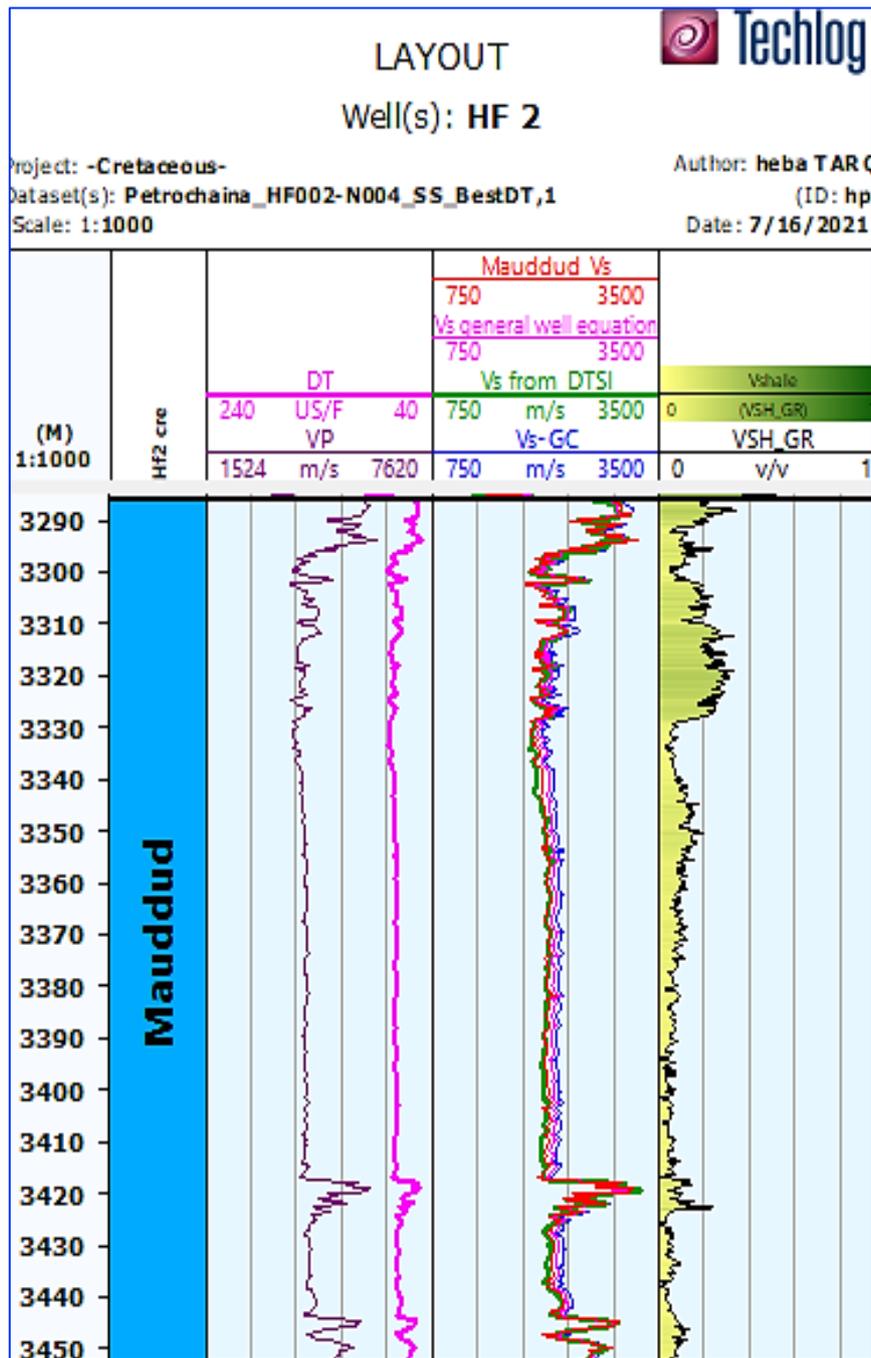


Fig.11.The CPI image represents the distribution of compression wave and shear wave velocities with depth of Mauddud Formation. The general equation obtained for Hf-2 well (pink), spatial formation equation Vs (red), DSI Vs that reflects velocity measured from dipole shear sonic log and Greenberg and Castagna equation (blue)

6. Conclusions

This study used the first order least square method to obtain an empirical equation for the considered formations (Mishrif, Rumiala, Ahmadi and Mudded). General equations were obtained for determining Vs from Vp values for all formations in Hf-2 well. Four equations for the considered formations in addition to a general equation for Hf-2 well were obtained. For Mishrif, Rumiala and Mauddud formations, the obtained equations with Greenberg and Castagna equation value are closest to the measured values of DSI Vs in Iraq. While for Ahmadi Formation the three measured velocities

are consistent each other but there are differences From DSI and Vs. The difference in the Ahmadi Formation may be due to the high percentage of shale volume and high porosities in this formation compared with other formations. The current study confirmed that the obtained equations can be used to determine Vs from Vp values for the considered formation and those in Hf-2 well and in other regions for all carbonate rock formations in Iraq.

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