



Acoustic Velocities as a Function of Changes in Confining Pressure of Kessanapalli Area of KG Basin

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Summary

Compressional and Shear wave velocities (V_p & V_s) have been measured on dry and NaCl saturated core plugs of Kessanapalli area of KG Basin under ambient as well as reservoir confining pressure conditions. The acoustic velocities have been found to increase with the increase in confining pressure and increase being most pronounced in the lower range of confining pressures. However when the core plugs are saturated with brine, the increase in velocities is not much as compared to that of dry plugs. The acoustic velocity data generated is then plotted which show simple linear relationships between V_p and V_s . For dry core plugs, the V_p - V_s curve passes through zero indicating a constant Compressional to Shear wave velocity ratio of 1.66. However, for NaCl saturated core plugs, the relationship between V_p and V_s under reservoir confining pressure conditions is found to be as follows:

$$V_p \text{ (m/sec)} = 1.55 V_s + 266$$

Also the velocities have been found to correlate linearly with porosity. The relationships of Compressional and Shear wave velocities with porosity show that the velocities decrease with increase in porosity. Based upon these relationships, the matrix velocities V_p & V_s arrived at are 4675m/sec & 2734m/sec for Kessanapalli area of KG basin.

Introduction

Compressional velocity alone is not a good lithology indicator because of the overlap in V_p for various rock types. The additional information provided by shear velocity can reduce the ambiguity involved in interpretation. The velocity ratio V_p/V_s is a very useful parameter in the determination of rock properties. Previous laboratory and well log studies have suggested correlations between lithology, porosity and V_p/V_s values. The ratio of V_p to V_s has been used as a lithology indicator by Pickett. He demonstrated that the velocity ratio V_p/V_s is a very good lithology indicator through his laboratory research and determined its value of 1.9 for limestone, 1.8 for dolomite and 1.6 for clean sandstone. This distinct difference in the values of V_p/V_s for limestones, dolomites and clean sandstones appears to result from the difference

in Poisson's ratio ' σ ' of the matrix material, namely quartz and calcite.

Also, the influence of brine saturation and confining pressure on acoustic velocities in rocks has been studied by Wyllie et al. (1958, 1962), Gregory (1963) and King (1966). These workers have reported that an increase in confining pressure increases both the V_p as well as V_s .

It is also well established that the primary factor affecting acoustic velocities in porous media is porosity. Various approaches to analyze the effect of porosity on velocity include the time-average equation (Wyllie et al., 1956), the Pickett empirical equation (Pickett, 1963) and the transit-time to porosity transform of Raymer et al. (1980). Shear wave velocity is thought to be more sensitive than the Compressional velocity to porosity (Domenico, 1984)

The confining pressure has been taken as 3200 psi. The study comprised of 19 core plugs from two wells of a field of KG Basin. The acoustic velocities have been measured



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by increasing the confining pressure from 200 psi to 4000 psi. The relationships between V_p and V_s have been established for dry as well as NaCl saturated core plugs. The relationships have also been established between V_p & V_s vs porosity. Relationship between transit time ($1/V_p$) and porosity has also been established.

Theory and Methodology

After cleaning the core plugs thoroughly and making them free from foreign materials, porosities and permeabilities were measured on dry core plugs. Acoustic velocities were determined through the Acoustic velocity measurement system by increasing the confining pressure from 200 psi to 4000 psi. Plugs were then fully saturated with brine to determine porosity (ϕ) and saturated bulk density (ρ_b) by saturation method. The acoustic velocities were determined on saturated core plugs by increasing the confining pressure as was done on dry plugs.

For determination of V_p and V_s , the core plug is placed in the pressure vessel between two platens which consist of piezoelectric transducers, one of which acts as an emitter and the other as a receiver. A Compressional ultrasonic (P) and two orthogonally polarized shear waves (S1 & S2) are propagated through the core sample. A short duration electrical pulse is supplied to the emitter transducer which is converted into mechanical wave on impact by the emitter. This wave is now transmitted to the core sample. After traveling through the core sample, the pulse is picked up by the receiving transducer, reconverted to an electrical signal and complete waveform is displayed on the oscilloscope. The velocities are calculated as follows:

$$V_p = L / \Delta T_p$$

$$V_s = L / \Delta T_s$$

Where V = Pulse propagation velocity in m / sec.

L = Pulse travel distance in centimeters

ΔT = Effective pulse travel time (i.e. measured time minus zero time correction)

Sonic travel time $\Delta T = 1/V$

This is done under ambient as well as reservoir confining pressure conditions by applying pressures with the help of a hand pump provided for this purpose.

Results & Discussion

The values of Compressional and Shear wave velocities (V_p & V_s) on individual dry and saturated core plugs of Kessanapalli area of KG basin under ambient as well as

reservoir confining pressures along with the values of the ratio V_p/V_s are given in Table-1. The data indicates that the velocities increase as the confining pressure is increased and therefore, the velocities at reservoir confining pressure are more as compared to those at ambient conditions.

Also, for dry core plugs, the relationships between V_p and V_s show linear trends passing through zero giving a constant value for the ratio V_p/V_s (Figure-1).

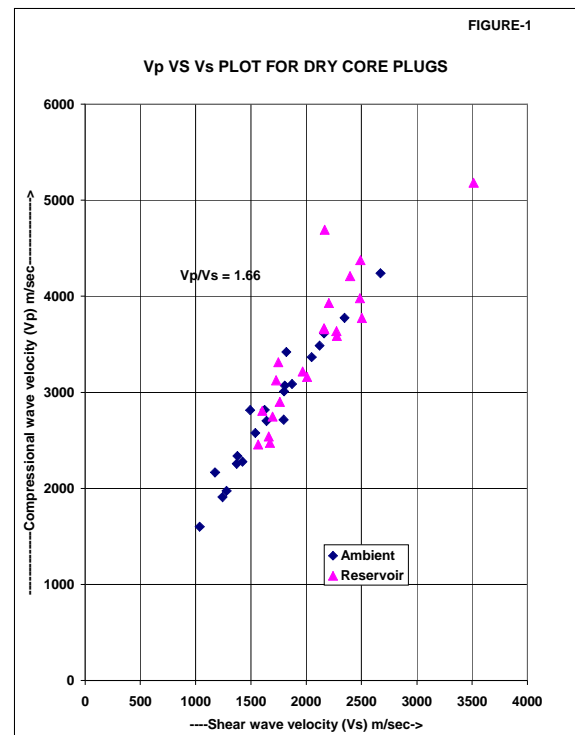


Figure 1: Compressional vs Shear wave velocity plot for dry core plugs

However, when the core plugs are saturated with brine, it is found that the acoustic velocities increase as compared to those of dry plugs both under ambient as well as under reservoir confining pressure conditions.

The relationship established between V_p and V_s for brine saturated core plugs under reservoir pressure conditions is given by the following equation (Figure-2):

$$V_p \text{ (m/sec)} = 1.55 V_s + 266$$



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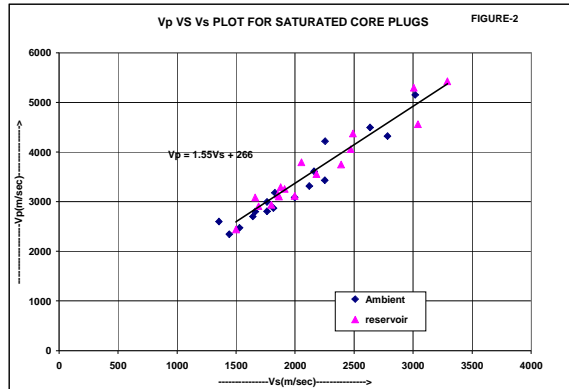


Figure 2: Compressional vs Shear wave velocity plot for saturated core plugs

Similar relationships have also been established by Costagna et al (1985) and Han et al (1986) with different values of coefficients for water saturated clastic silicate rocks and sandstones respectively.

The velocity data on saturated core plugs shows a considerable degree of dependence of velocity upon porosity. Both V_p and V_s correlate linearly with porosity (Figure-3). The V_p - ϕ and V_s - ϕ cross-plots on a linear scale give the following relationships:

$$V_p = 4675 - 64.546 \Phi$$

$$V_s = 2734 - 35.33 \Phi$$

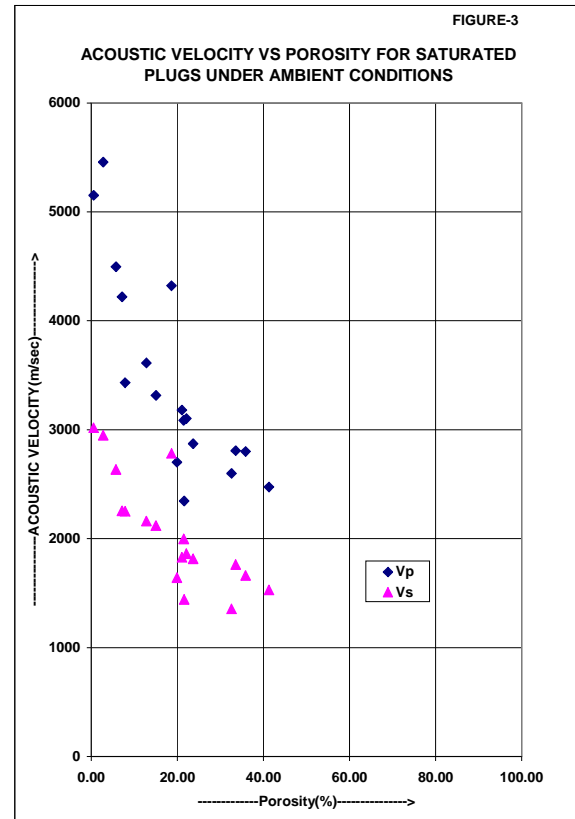


Figure 3: Compressional/ Shear wave velocity vs porosity plot for saturated core plugs

The relationship between transit time and porosity has also been established as:

$$\phi = 0.5405 \Delta T - 31.22$$

which gives a matrix time of about 58 $\mu\text{sec}/\text{ft}$.

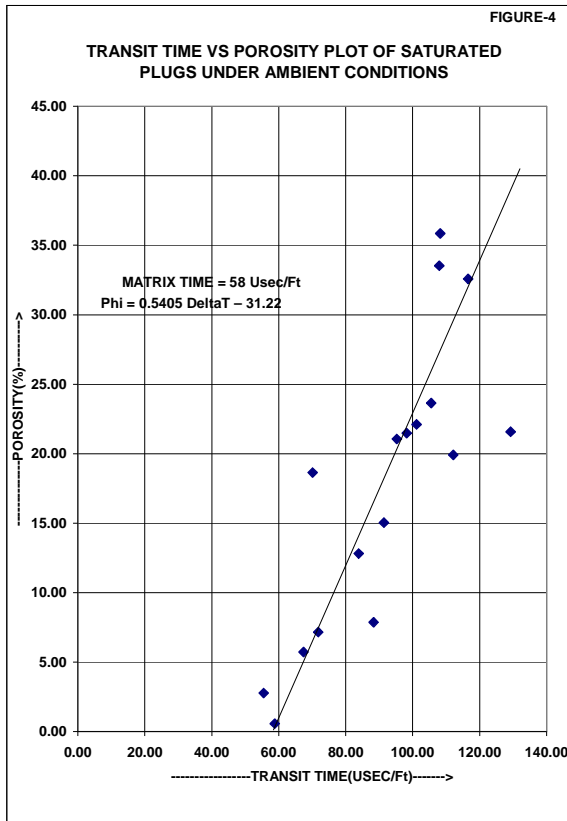


Figure 4: Transit time vs porosity plot for saturated core plugs

Velocity vs confining pressure plots (Figure Nos. 5a to 5d) show how the velocities are changing with changes in confining pressure. These plots clearly indicate that the changes in velocity with changes in confining pressure are more pronounced in lower region of the confining pressure and at higher pressures, the changes in velocity are not appreciable. It has also been observed that the velocities become constant after a certain confining pressure and do not change with increase in pressure.

Figure No. 5d shows the plot for plug no. 26 which has only dry measurements as the plug got broken during saturation.

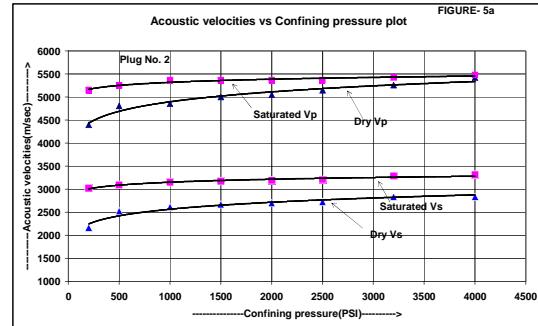


Figure 5a: Velocity vs Confining pressure plot (Plug No. 2)

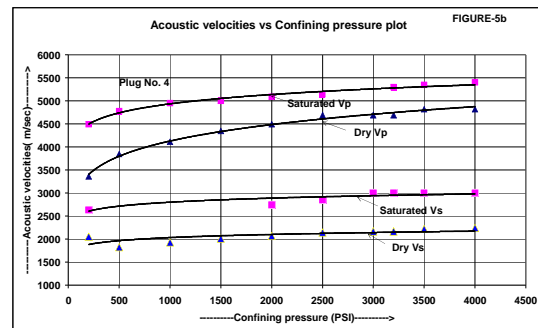


Figure 5b: Velocity vs Confining pressure plot (Plug No. 4)

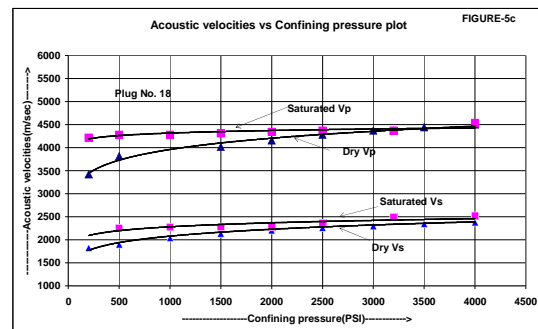


Figure 5c: Velocity vs Confining pressure plot (Plug No. 18)

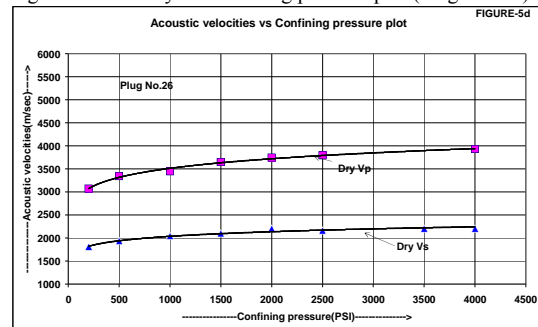


Figure 5d: Velocity vs Confining pressure plot (Plug No. 26)



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Conclusions

The experiments show that the velocities under reservoir confining pressure are more than those at ambient conditions. For dry core plugs, there is a marked increase in velocities with increase in confining pressure. When the core plugs are saturated with brine, the velocities increase as compared to those of dry plugs under ambient conditions.

There is a linear relationship between V_p and V_s . For dry core plugs, the V_p - V_s plot passes through zero giving a constant value of the ratio V_p/V_s which comes to around 1.66 both under ambient and reservoir confining pressure conditions. However, it has been observed that the brine saturated linear trend does not pass through zero and V_p - V_s plot intercepts on the V_p axis giving a finite value of V_p while V_s has become zero. The ratio V_p/V_s increases as we approach $V_s = 0$.

The velocities have also been found to have a considerable degree of dependence on porosity despite scatter. Our data shows that both V_p and V_s correlate linearly with porosity and the velocities decrease with an increase in porosity. The decrease in Compressional wave velocity is sharp as compared to that of Shear wave velocity. The matrix velocities V_p & V_s obtained are 4675 m/sec and 2734 m/sec. The Transit time-Porosity relationships can be used for determination of porosity from transit times recorded in the wells of Kesanapalli area of KG basin.

Sl No.	Plug No.	Dry Plugs						Saturated Plugs					
		Ambient conditions			Insitu conditions			Ambient conditions			Insitu conditions		
		V_p (m/sec)	V_s (m/sec)	V_p/V_s	V_p (m/sec)	V_s (m/sec)	V_p/V_s	V_p (m/sec)	V_s (m/sec)	V_p/V_s	V_p (m/sec)	V_s (m/sec)	V_p/V_s
1.	KW1	4240	2672	1.59	5182	3514	1.47	5457	2948	1.85	5764	3109	1.85
2.	KW2	4397	2161	2.03	5426	2833	1.91	5152	3018	1.71	5426	3290	1.65
3.	KW4	3365	2050	1.64	4693	2166	2.17	4496	2635	1.71	5297	3006	1.76
4.	KW5	2279	1424	1.60	3161	2008	1.57	--	--	--	--	--	--
5.	KW6	2702	1642	1.65	2900	1761	1.65	2702	1642	1.65	2939	1798	1.64
6.	KW7	2255	1370	1.72	2748	1696	1.62	2345	1442	1.63	2443	1499	1.63
7.	KW8	2165	1176	1.84	2807	1602	1.75	2807	1762	1.59	3256	1911	1.70
8.	KW9	1974	1280	1.54	2457	1566	1.57	2800	1662	1.68	3143	1855	1.69
9.	KW10	1910	1242	1.54	2540	1662	1.53	2599	1355	1.92	3083	1662	1.86
10.	KW11	1600	1037	1.54	2474	1672	1.48	2473	1529	1.62	2909	1690	1.72
11.	KW12	2815	1493	1.89	3656	2165	1.69	3181	1828	1.74	3292	1877	1.75
12.	KW13	2576	1540	1.67	3125	1728	1.81	2872	1816	1.58	3795	2053	1.85
13.	KW14	3086	1871	1.65	3217	1968	1.63	2995	1762	1.70	3102	1863	1.67
14.	KW16	2337	1378	1.70	3775	2504	1.51	3431	2251	1.52	3556	2181	1.63
15.	KW18	3420	1820	1.88	4375	2490	1.76	4220	2254	1.87	4375	2490	1.76
16.	KW20	3775	2346	1.61	4210	2397	1.76	4321	2783	1.55	4561	3041	1.50
17.	KW21	2715	1796	1.51	3636	2273	1.60	3315	2120	1.56	3750	2390	1.57
18.	KW22	3613	2161	1.67	3981	2486	1.60	3613	2161	1.67	4057	2471	1.64
19.	KW23	3010	1799	1.67	3587	2277	1.58	3085	1997	1.55	3116	1997	1.56
20.	KW24	2818	1624	1.74	3312	1748	1.89	--	--	--	--	--	--
21.	KW25	3485	2120	1.64	3667	2160	1.70	--	--	--	--	--	--
22.	KW26	3071	1807	1.70	3930	2204	1.78	--	--	--	--	--	--

TABLE-1



References

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Acknowledgements:

The authors are thankful to Sh. Jokhan Ram, ED-Chief, KDMIPE for the encouragement and facilities provided during the study. They are also thankful to Sh. D. Sar, GM-Head, GPRG for providing constant guidance during the course of the study. They are also thankful to Sh. Kalika Prasad, DGM (Wells) and Head, Petrophysical Research Division, for critically reviewing the paper.