IJCPE
Iraqi Journal of Chemical and Petroleum Engineering

Iraqi Journal of Chemical and Petroleum Engineering
Vol.15 No.2 (June 2014) 9- 14
ISSN: 1997-4884

University of Baghdad
College of Engineering

Using Sonic Log to Predict Abnormal Pressure Zones in Selected Oil Wells (Western of Iraq)

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Abstract

Two oil wells were tested to find the abnormal pressure zones using sonic log technique. We found that well Abu-Jir-3 and Abu-Jir-5 had an abnormal pressure zones from depth 4340 to 4520 feet and 4200 to 4600 feet, respectively. The maximum difference between obtained results and the field measured results did not exceed 2.4%.

In this paper, the formation pressures were expressed in terms of pressure gradient which sometimes reached up to twice the normal pressure gradient.

Drilling and developing such formations were dangerous and expensive.

The plotted figures showed a clear derivation from the normal trend which confirmed the existence of abnormal pressure zones.

Keywords: Normal pressure, Subnormal pressure, Abnormal pressure, Formation pressure, Formation pressure gradient, Transition zone

Introduction

Abnormal pressures have been identified in about 180 sedimentary basins and most oil and gas generation in such basins occurs within the over0pressured fluid compartments [1].

Knowledge of the pressure distribution in a given area frequently minimizes the problems associated with all phases of operation: geophysics, geological, drilling and petroleum engineering. Certainly, the most serious problem met by the group of oil well drilling is that of abnormal pressure zones. This problem is related to tertiary geological age and it has, as mentioned before, a direct relation to geophysical prospecting, geological structures and petroleum engineering.

Generally, normal pressure is considered with formation pressure which is approximately equal to hydrostatic head of water column if the formation is opened to the atmosphere and this is equal to 0.465 psi/ft which is called pressure gradient (p.g) while abnormal pressure zones are those which have (p.g) more than 0.465 psi/ft [2]. It may reach twice of this value as observed in the North Sea. Working with such formations is hazardous and very expensive [3]. It is interesting to mention that there is an upper transition zone through which there are indications of existence of abnormal pressure zone.

Studies in petroleum industry showed that the rate of penetration is reduced by an increase in the mud column pressure [4]. As we go deeper and deeper the penetration rate is decreased because we will be met by harder rocks. This trend has been reversed through drilling over pressured zones and the pressure gradient will be largely increased [5]. In other words, in an abnormal pressure zones, the mud weight should be increased to balance the formation pressure.

Many studies showed that the shale density and/or resistivity can be used to detect the over pressured zone [6, 7, 8]. The geological section of the studied area is shown in Fig.1 and the location map of the studied area is shown in Fig.2 In this work, we have applied the sonic log techniques at selected wells which gave accurate results compared with field data.

Causes of Abnormal Pressure

1- Very rapid deposition of large quantities of sands and shale predominating may result in sand bodies that are completely surrounded by shale and as compaction progressives, water is unable to escape and this give an abnormal pressure zone especially if the rock still has sufficient tensile strength [9].
2- Abnormal pressure refers to areas of high topographic relief where the outcrop of the pressured sand acts as an elevation high enough to cause artesian head; this is especially true in rapid filling (tertiary) sedimentary basins [10].
3- Thick gas cap at the interface of water/gas is caused by growth faults [11].
4- Fluid transfer is due to the alteration of montmorillonite to illite [12].
5- Routes of communication between beds having different pressures are available [12].
6- There are other miscellaneous causes such as reverse osmosis which is the movement of ions in water down a water concentration gradient (i.e. from fresh to saline). The ions will continue to move until the salinities balance or pressure prevents further movement. That pressure is postulated to be as much as 4000 psi in the subsurface where shales can act as the semipermeable and mineral decomposition such as the transformation of gypsum to anhydrite ($CaSO_4.2H_2O$ to $CaSO_4$) and the release of water of crystallization [11, 12].

Results and Discussion

The data and the results concerned with the wells Abu – Jir3 and Abu – Jir5 are listed in Table1 and Table2, respectively.

Figure1 shows a typical log Δt_{sh} versus depth of well Abu – Jir3. The normal curve was constructed on the log and deviation of Δt_{sh} from the normal trend clearly began at about 4340 feet which was the depth at which abnormal pressure started. In this well, a normal pressure gradient of 0.465 psi/ft was measured and was increased in the adjacent shales (from depth 4360 to 4520 feet). The normal Δt_{sh} curve began at 60μsec/ft at depth equal to 4320 feet and decreased logarithmically to 15μsec/ft at 4520 feet.

In the same concept, Figure4 shows abnormal pressure zone from depth 4200 to 4600 feet.

A correlation was made from sonic log data relating the difference Δt_{sh} observed and Δt_{sh} in normally pressured zones to the formation pressure gradient, as shown in Figures 5 and 6, respectively. From these figures, an estimation of the formation pressure gradient and as a result formation pressure at any depth may be obtained.

Conclusions

1- The use of the Sonic Log to detect the beginning of abnormal pressure zone was applied with good results in the studied area.

2- The interval transit time recorded by Sonic Log might be thought of as function of lithology and porosity. In other words, since the porosity of the shales decreased with compaction, Δt_{sh} should decrease with depth. This was shown in Figures 3 and 4.

3- Plotting of pressure gradient with difference in Δt_{sh} and equivalent mud weight (Figures 5 and 6) could be used to evaluate a given drilling objective through determining mud weight and hence casing requirements at any depth.

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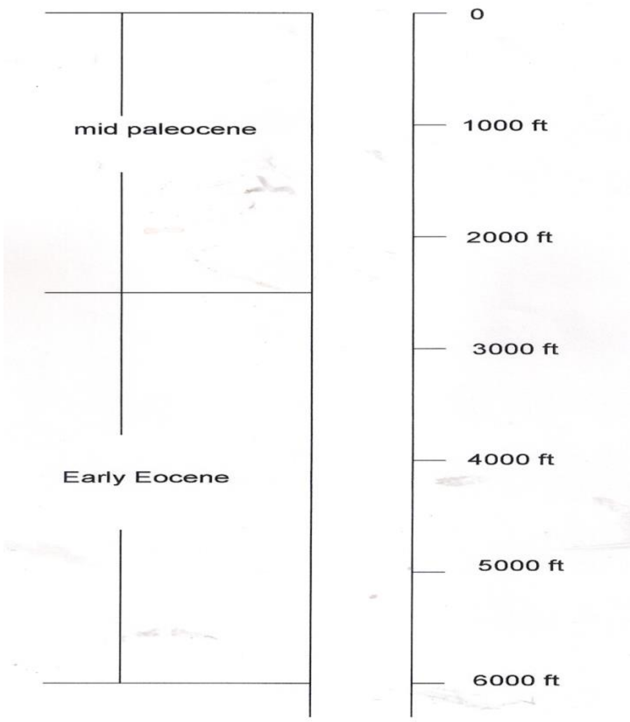

Fig. 1: Geolgoical section of the studied area (after Sissakian , 2000)

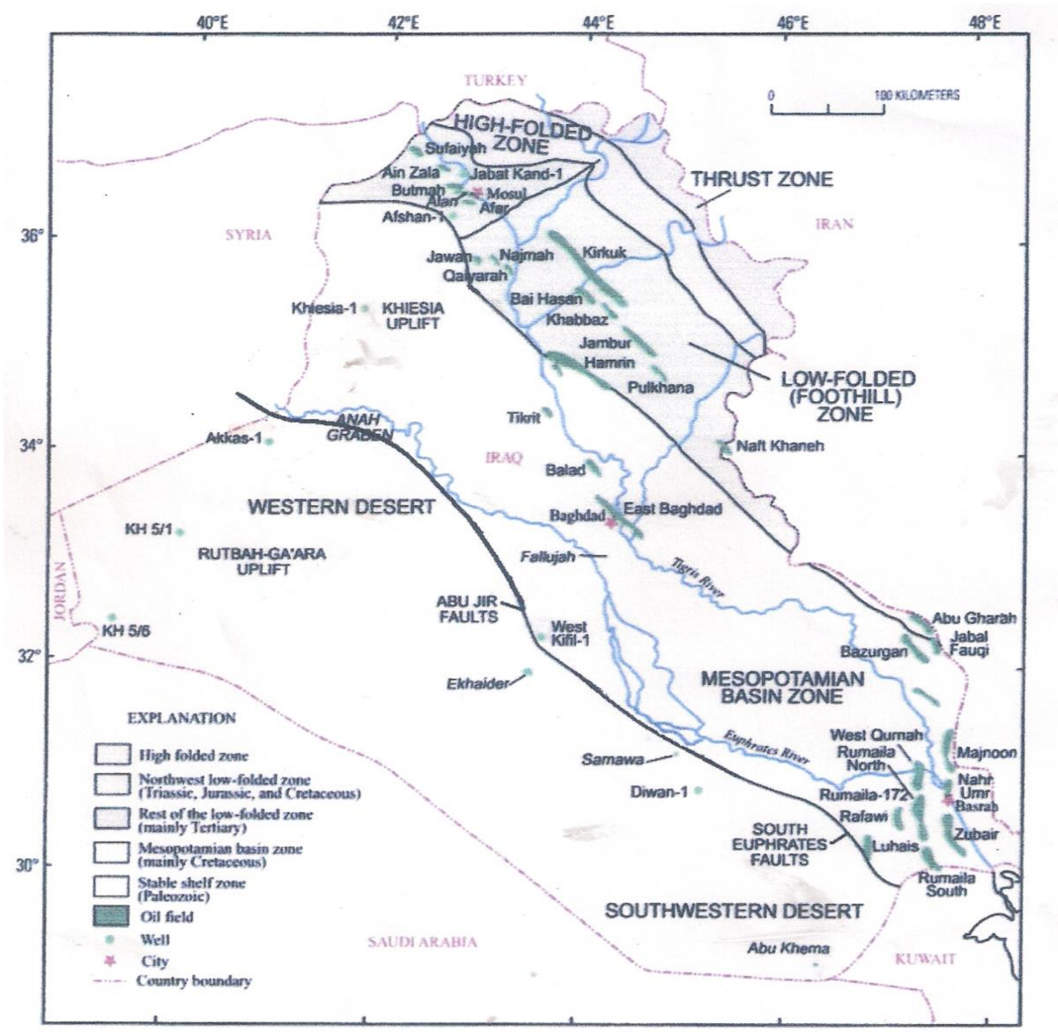

Fig. 2: Location map of the studied area

Table 1: Well Abu – Jir 3 Pressure estimation from sonic log data

Depth Ft	Δt nor. µSec/ ft	Δtobs. µsec/ft	Δtobs. - Δtnor.	F.P.g	Pressure Psi	Equivalent mud weigh P.P.g
4320	60	60	0	0.465	2008.8	8.937
4340	50	50	0	0.465	2081	8.937
4360	40	50	10	0.6	2616	11.533
4380	40	55	15	0.62	2715.6	11.916
4400	30	60	30	0.83	3652	15.952
4420	25	65	40	0.93	4110.6	17.875
4440	23	70	47	0.94	417306	18.067
4460	20	60	40	0.93	4147.8	17.875
4480	17	40	23	0.81	3628.8	15.568
4500	15	45	30	0.88	3735	15.953
4520	15	35	20	0.80	3616	15.568

Table 2: Well Abu – Jir 5 Pressure estimation from sonic log data

Depth Ft	Δt nor. µSec/ ft	Δtobs. µsec/ft	Δtobs. - Δtnor.	F.P.g	Pressure Psi	Equivalent mud weigh P.P.g
3700	300	300	0	0.465	1720.5	8.937
3750	250	250	0	0.465	1743.75	8.937
3800	150	150	0	0.465	1767	8.937
3850	210	210	0	0.465	1790	8.937
3900	190	190	0	0.465	1813.5	8.937
3950	200	200	0	0.465	1836.75	8.937
4000	190	190	0	0.465	1860	8.937
4050	180	180	0	0.465	1883	8.937
4100	150	150	0	0.465	1906.5	8.937
4150	145	145	0	0.465	1929.75	8.937
4200	110	120	10	0.6	2520	11.532
4250	110	150	40	0.93	3922	17.367
4300	105	155	50	0.44	4042	18.067
4350	100	160	60	0.9345	4065	17.961
4400	95	170	75	0.942	4144.8	18.105
4450	85	155	70	0.935	4140.75	17.884
4500	77	130	53	0.941	4234.5	18.086
4550	72	110	38	0.91	4140.5	17.490
4600	68	100	32	0.89	4094	17.106

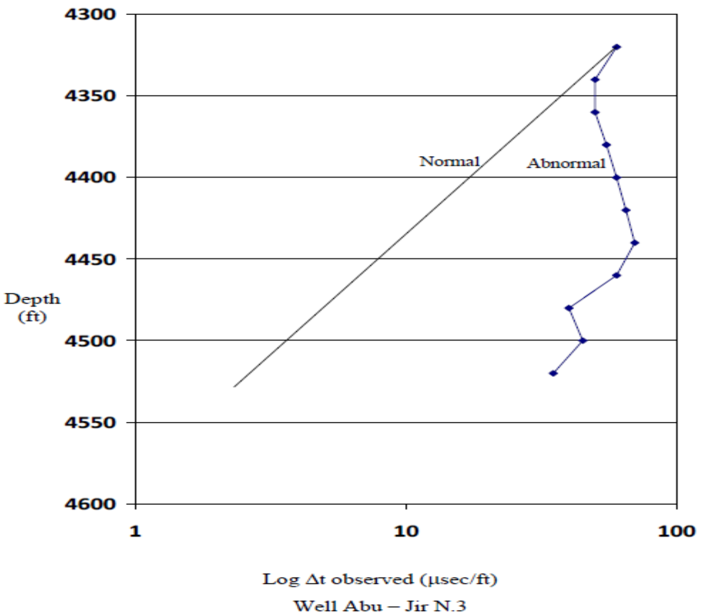

Fig. 3: Pressure estimation from sonic log data

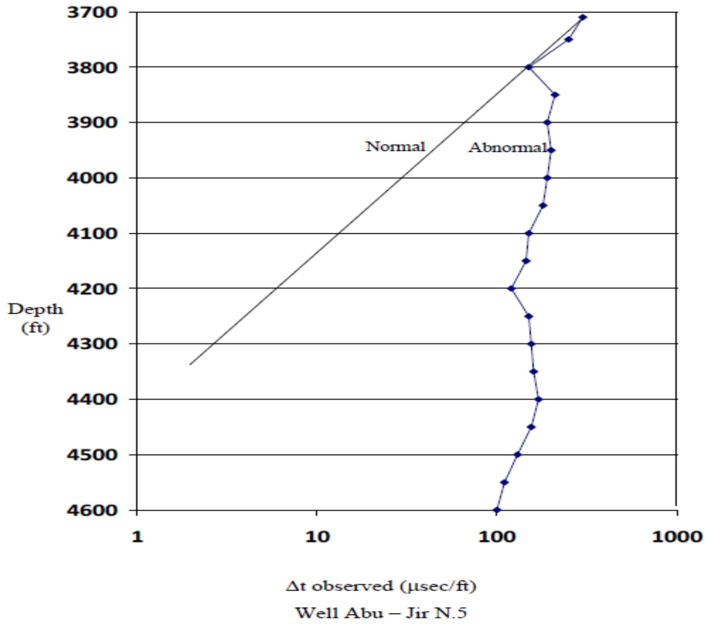

Fig. 4: Pressure estimation from sonic log data

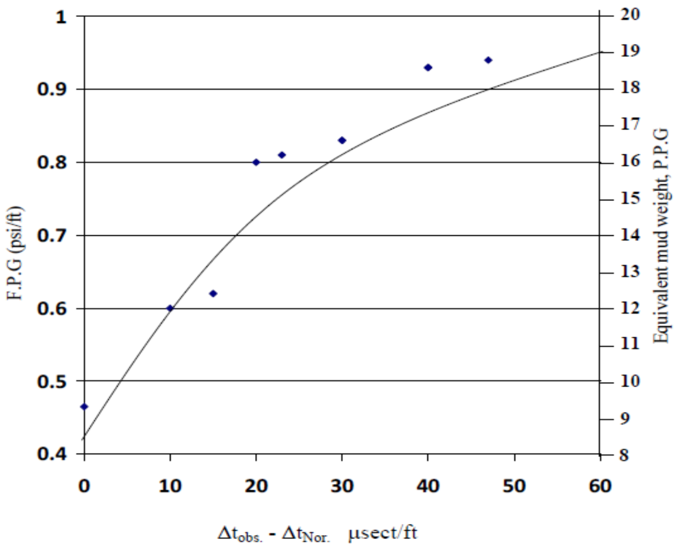

Fig. 5: Relationship of (pressure gradient, travel time and equivalent mud weight) in Abu – Jir 3

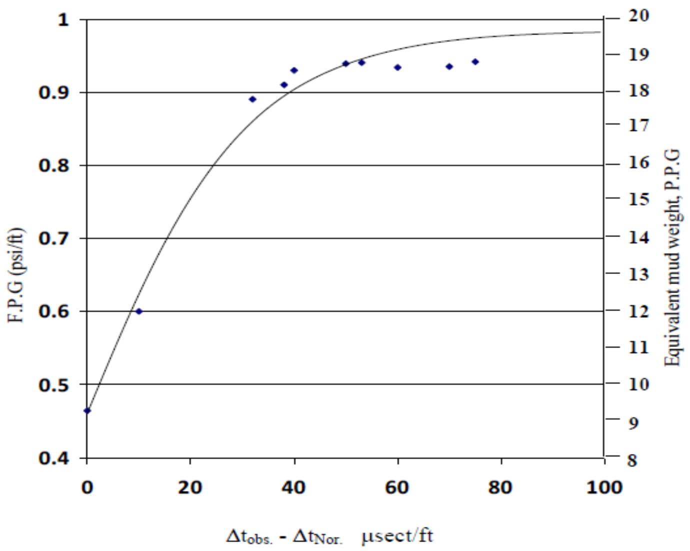

Fig. 6: Relationship of (pressure gradient, travel time and equivalent mud weight) in Abu – Jir 5