GLOBAL JOURNAL OF ENGINEERING RESEARCH VOL. 3, No. 1 & 2, 2004: 39 - 46
 ISSN 1596-292X

ANALYSIS OF PORE PRESSURE USING GEOPHYSICAL METHODS.

A. DOSUNMU and U. NWAGBARA

(Received 5 August 2002; Revision Accepted 23 September 2002)

ABSTRACT

Many methods have been devised for predicting and evaluating the values of pore pressure in oil and gas formations. The present work employs geophysical approach for prediction of formation pore pressure in Niger Delta. This involved the use of seismic derived data before drilling operation, which was correlated with sonic, and density logs data gathered after drilling. The analysis shows that at a depth of about 11177ft when interval transit time starts to increase, high pore pressure is likely to be encountered. At SP 257, which is about 3miles from a proposed drilling location, it is predicted that high pore pressure will occur at about 7600ft. Also at SP 1035, onset of abnormal pressure was predicted to be at 7300ft depth. Correlation with M W D resistivity data at SP 182 reveals that the prediction closely match the real values at shot point 1035 which is 500ft from the proposed well location.

KEYWORDS: Pore Pressure, Geophysical, Prediction

INTRODUCTION

Prediction of pore pressure especially before drilling is important in drilling, exploration and development of oil and gas fields. It is necessary in assessing the effectiveness of a regional top seal section, mapping of hydrocarbon migration pathways, analysis of trap configuration, determining the geometry of a prospective basin, and providing calibration to basin modeling. It also aids in well planning process by providing good information for proper casing and mud design programs which can help to prevent blow-outs, lost circulation and stuck pipes during drilling. Conventional techniques of predicting pore pressure have been limited by the requirement to establish a normal trend of an attribute (usually porosity indicator) and a set of calibrated curves relating overpressure to deviation from the normal trend of the attribute. Because of this, they are not suitable for use in wildcat and deepwater areas. A new integrated geophysical technique that has been developed where pressure derived from seismic velocity data is used for the Niger Delta formation. Through calibration, offsetting and correlation with data that can be gathered during well appraisal and development phase, the technique can provide prediction values that are dependable. However, drilling experience has shown that this approach can predict pressures to 0.5-0.75ppg accuracy at larger depths provided the low frequency trends of seismic interval velocities are of good quality and close to well velocities to within 5-10%. This study is limited to geophysical technique of pore pressure prediction before drilling in the Niger Delta where there is absence of tectonic activities. It does not predict effective stress defined as difference between overburden and pore pressure. Identification of the depth in the formation litho logy where maximum pore pressure could be encountered in order to incorporate it in drilling design will be achieved.

BACKGROUND OF THE STUDY

During drilling operations, well bore pressure must be maintained between naturally occurring pressure of the formation fluids and the maximum well bore pressure that the formation can withstand without fracture. Fluid pressure in the earth crust is a function of variations in the regional stress, temperature and composition of water rich fluids.

Formation pore pressure is the pressure acting upon the fluid in the pore space of a formation. It is hydrostatic pressure (weight of a column of fluid) within the pore space and its value can be found by using equation 1.

$$P_p = \rho g z \quad (1)$$

Where:

ρ = Fluid density
g = acceleration due to gravity
z = height of the fluid column
P_p = pore pressure.

The size and shape of the fluid column has no effect on the pore pressure but the fluid density depends on fluid type, concentration of dissolved

A. DOSUNMU, Department of Petroleum and Gas Engineering, University of Port Harcourt, Port Harcourt - Nigeria
U. NWAGBARA, Department of Petroleum and Gas Engineering, University of Port Harcourt, Port Harcourt - Nigeria

solid / gas in the fluid column and temperature of the fluid.

METHODS OF PORE PRESSURE DETERMINATION

Most pore pressure determination methods are based upon Terzaghi's equation, which states that;

$$Pp = \lambda - \sigma \quad \text{.........................} (2)$$

Where:

Pp = Pore pressure

λ = Overburden pressure

σ = Effective stress.

Pore pressure prediction method applicable before drilling utilizes seismic interval velocities, offset well logs and well histories to predict formation pore pressure. The methods include Equivalent Depth, Fillipone, Amoco approach, BP

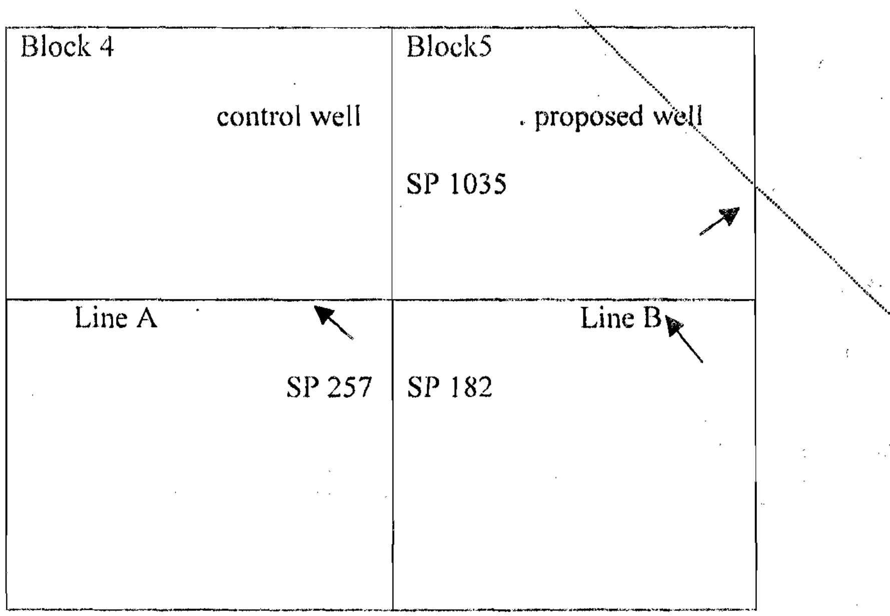

Fig.1 control and proposed well sites and two seismic lines at WX2 field

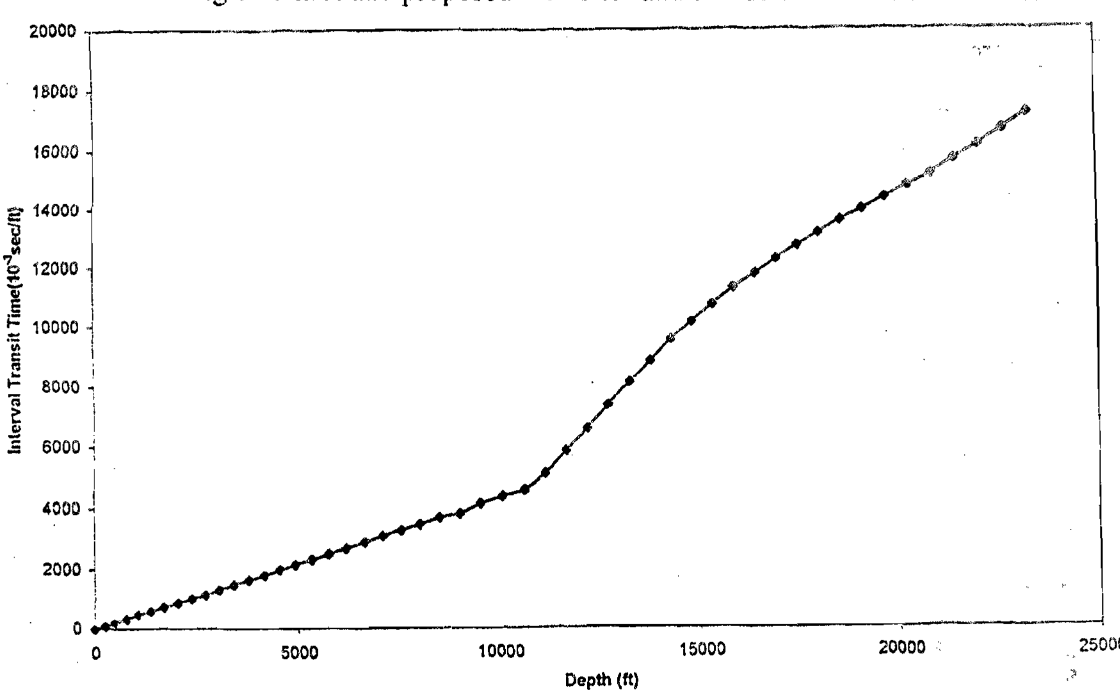

Fig.2 Plot of Depth against Interval Transit Time

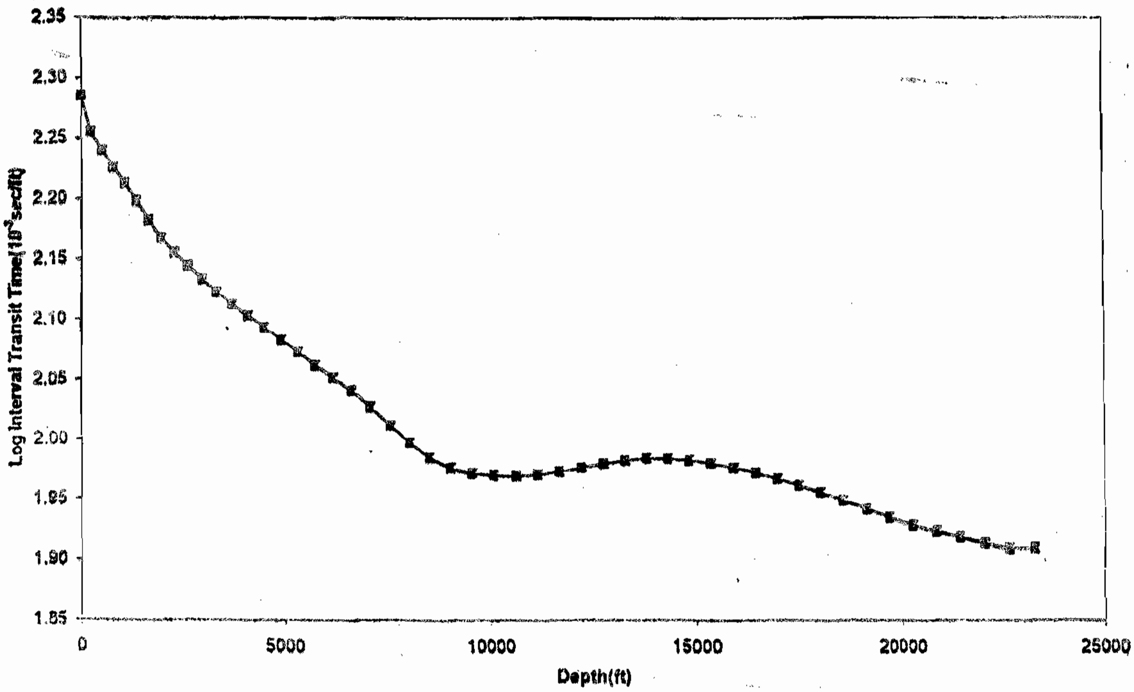

Fig.3 Plot of Depth against Log of Interval Transit Time

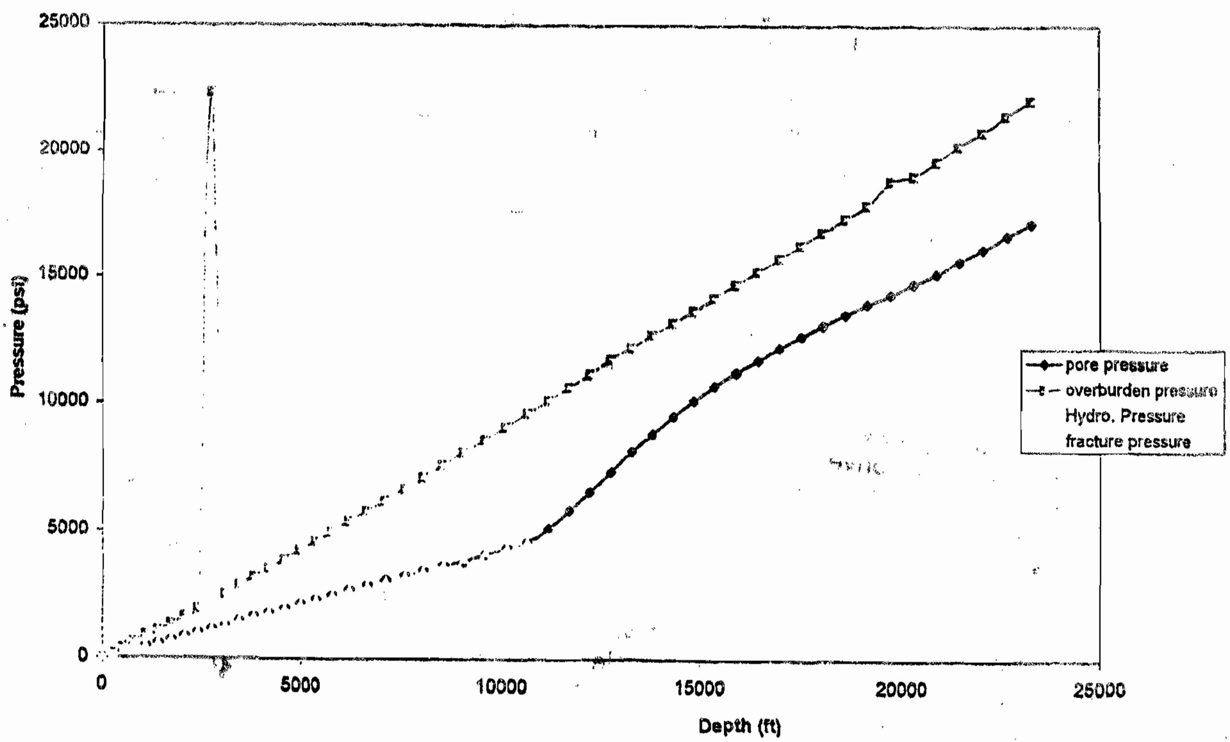

Fig.4 Plot of Depth against Pressure

approach and Cornet. The seismic interval velocity is based on the elementary reflection analysis. Analysis of the velocity is usually performed automatically by computer algorithm in standard surface seismic processing.

Interval transit time obtained from surface seismic velocity yield pore pressure and fracture gradient prior to drilling a well (Pennbaker, 1968). It is a function of pore pressure, lithology, geologic age and depth. The result which is usually obtained in

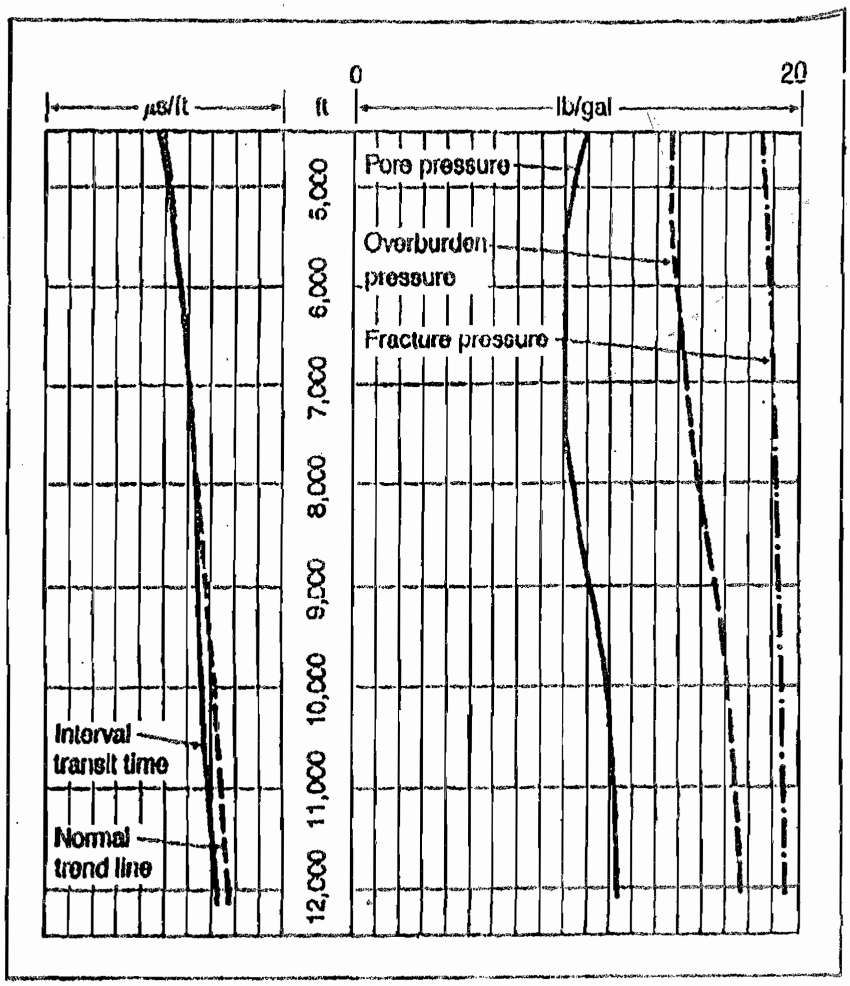

Fig. 5 – Computed results of pore pressure and fracture pressure derived from smoothed seismic velocity at SP 257.

form of an overlay of lines of equal pore pressure gradient is a convenient means of determining pore pressure from interval transit time plot. Holbrook, (1989) stated that pore pressure in lateral variations as a result of lithology variation could be obtained from reflection topography as velocity analysis. Similar proposition was made by Sayers et al (2000) that if the variation exists because of salt layers of variable thickness, seismic interpretation in formation with abnormally high pore pressure requires the understanding of how density and velocity of geopressured rocks vary with sedimentation rates, geothermal gradient, sediment deposition sequences and thickness, Dutta (1987).

DATA GATHERING

This approach involves the use of seismic velocity data to predict pore pressure before drilling. The quality-controlled data for the study was collected from the seismic operations carried out at WX field in Niger Delta. It is assumed to be representative of both offshore and swamp locations. Sonic and density logs data were also collected from the field after drilling for correlation with the predicted values.

DATA ANALYSIS

The seismic velocity data was analyzed to obtain the interval transit time by initially obtaining pre-stack migrated seismic data from which stacking velocities were obtained. Corrections for offset bias and anisotropy were made. For this study, the anisotropy is 1, which indicates that sonic and density logs data is equivalent to the seismic velocity data.

Using 3D geologic model, a horizon consistent with stacking velocities obtained was interpreted and laterally smoothened. The stacking velocities

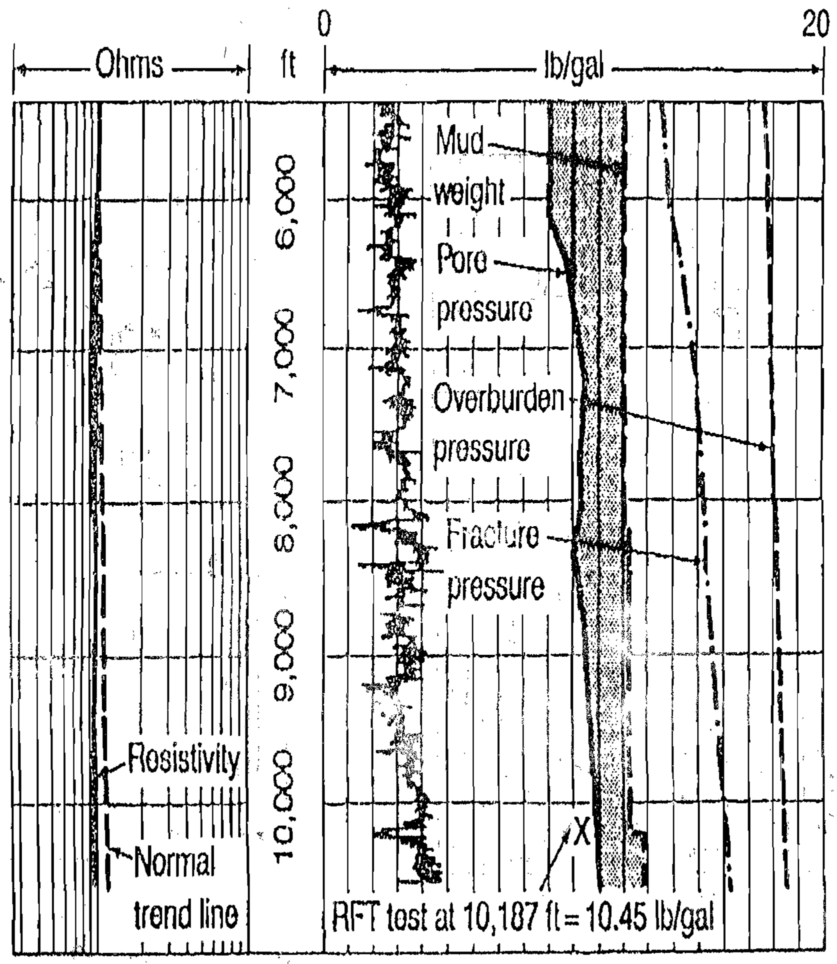

Fig: 6 Pore pressure from resistivity data

were then transformed to interval transit time using Dix Equation. The interval transit time obtained was smoothened laterally and vertically. Vertical effective Stress, Overburden pressure, Potential fluid pressure, Hydrostatic pressure and fracture pressure were transformed from seismic velocity data by using Pannebaker, Eaton, Christman and Dix Equations. Pore pressure was thereafter determined by using effective stress law.

Both semi logarithmic and linear plots of interval transit time against depth were plotted to show the region of changes in pore pressure. Multiple regression plots were also produced to show the relationship between depth and other parameters required to predict formation pore pressure.

By using a control well of about three miles from a proposed well drilling location on the field, a seismic line parallel to the two at 2,500ft offset was drawn (fig.1) and interactive velocity analysis was performed on the line at shot points SP 257 and 182 corresponding to the two well locations.

RESULTS AND DISCUSSIONS

Two-way reflection time and velocity for various depths obtained from the seismic operations was used to produce the plots of interval transit time against depths (fig 2 and fig 3). High pore pressure is likely to be encountered at about 11177ft. At this depth, the interval transit time starts increasing and later reduces to produce the overpressure zone in the formation.

Possible increase in porosity at the depth could be responsible for the occurrence. Also at this depth, there is decrease in the vertical effective stress and increase in overburden, minimum hydrostatic stress and hydrostatic pressure (fig 4)

Pore pressure and fracture pressure computed from the smoothened velocity data for the shot point 257 that correspond to the location of the control well is shown in fig (5). The standard compaction trend line is overlain on the section of interval transit time. The interval transit time

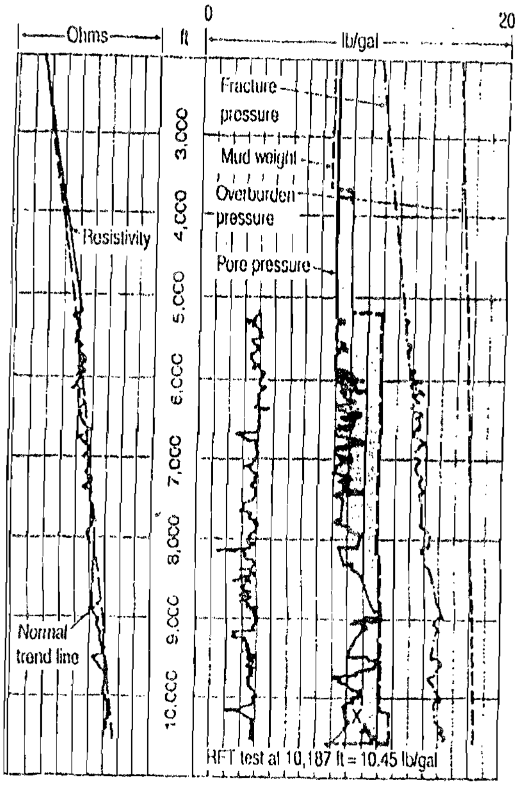

Fig: 7 Pore Pressure from sonic data

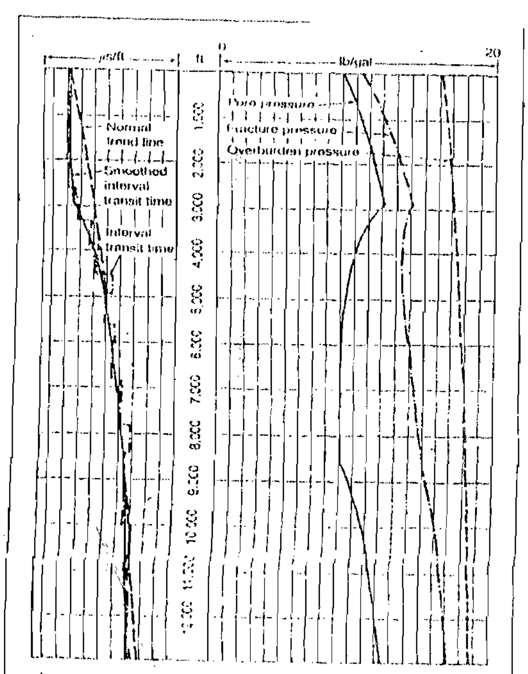

Fig:8 Pore pressure obtained from seismic data at Sp 182

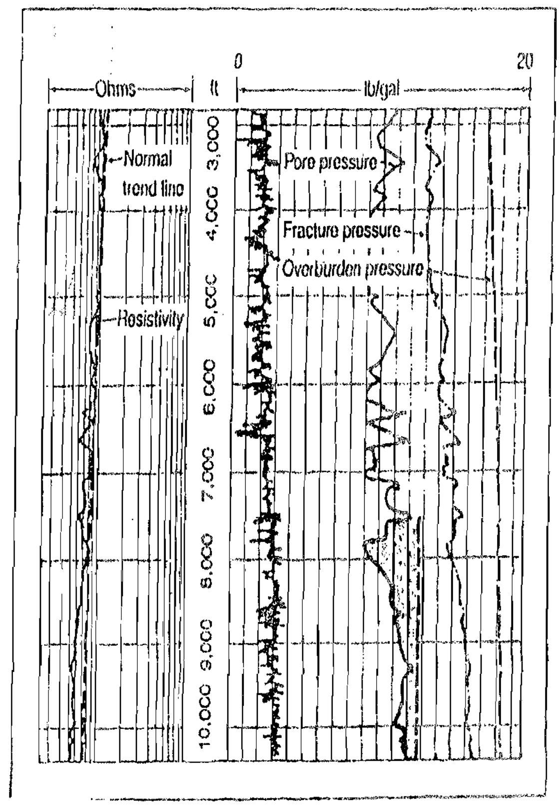

Fig: 9. Pore pressure obtained from seismic data of Sp 1035, just 500ft from the proposed site.

deviated to the left of the normal trend reflecting an increase in pore pressure. The onset of abnormal pressure is about 7,600ft and increases toward total depth. Comparing this to the pore pressure profile obtained from resistivity and sonic logs data presented in fig (6) and fig (7), the overpressure occurs at depth above 7,600ft though major abnormal pressure occurs below the depth as shown in fig (5).

For SP 182 and 1035, the pore pressure profiles are shown in fig (8) and fig (9) using the seismic interval transit time. The seismic line offsets the proposed well location by 2,500ft. The result for SP 1035 which is 500ft from the proposed well location, indicated that normal pressure exist to a depth of 7,300ft at which point an abnormal pressure gradient is likely to be encountered. Actual MWD resistively data from the wellsite presented in fig (10) is compared to the plot obtained at SP182. It shows that onset of abnormal pressure is 7,300ft. This closely match the real data obtained for SP 1035.

CONCLUSION

The depth range of about 7,300-7,600ft has been

depth	pore pressi	overburder	Hydro. Pre:	fracture pressure
0	0	0	0	0
252	107	191	107	162
521	224	401	224	341
803	346	627	346	533
1096	473	865	473	735
1397	603	1114	603	947
1708	738	1375	738	1169
2031	877	1647	877	1400
2365	1022	1934	1022	1644
2710	1171	22333	1171	1898
3064	1325	2542	1325	2161
3427	1483	2863	1483	2434
3799	1643	3192	1643	2713
4180	1809	3535	1809	3004
4570	1977	3883	1977	3300
4969	2150	4245	2150	3608
5377	2326	4615	2326	3922
5795	2508	5000	2508	4250
6222	2693	5393	2693	4584
6661	2883	5801	2883	4731
7110	3087	6221	3078	5288
7573	3278	6657	3278	5659
8050	3484	7109	3484	6043
8545	3699	7584	3699	6446
9055	3819	8075	3919	6864
9578	4146	8585	4196	6298
10108	4375	9100	4375	7735
10642	4607	9623	4607	8179
11178	5150	10149	4839	8622
11714	5845	10671	5071	9070
12247	6581	11190	5301	9511
12776	7349	11780	5531	9952
13302	8113	12219	5759	10386
13824	8840	12766	5985	10817
14344	9528	13232	6210	11247
14863	10152	13735	6435	11674
15382	10735	14238	6659	12102
15904	11280	14744	6885	12532
16430	11783	15255	7212	12967
16960	12269	15773	7343	13407
17496	12737	16296	7574	13851
18039	13178	16830	7810	14305
18589	13598	17368	8047	14763
19147	14002	17919	8289	15231
19714	14381	18881	8534	15709
20290	14785	19055	8785	16196
20874	15207	19637	9037	16692
21467	15674	20232	9295	17197
22066	16163	20831	9553	17706
22672	16682	21441	9816	18225
23285	17203	22060	10082	18751

found to be of high pore pressure in the proposed wellsite at the WX2 field in Eastern Niger Delta by using geophysical approach. See fig. 11 for the Niger Delta area under study. Within this zone, overpressure is likely to be encountered. Casing and mud program can be therefore be properly designed, trap configuration can be well analyzed, regional top seal section can be assessed and hydrocarbon migration pathway can be mapped effectively by putting prediction in consideration.

When computing the pore pressure from seismic velocity data, a margin of error could have occurred in association with geologic faults and dipping beds. Therefore the prediction may be an accurate precursor of the formation pore pressure that could be encountered during actual drilling. Validation of the prediction is better from LWD and MWD data. Since just one pore pressure prediction technique cannot be used to generalize the result obtained for the field, other methods should be used and their results compared so that the prediction can be reliable.

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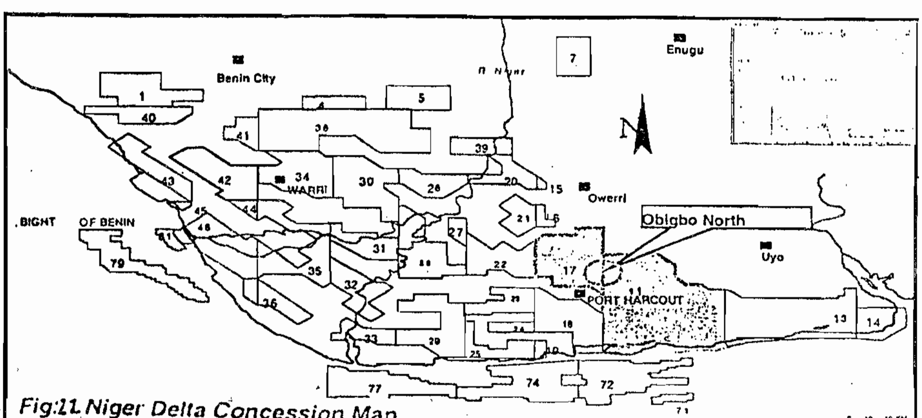

Fig:11 Niger Delta Concession Map