GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 7, NO. 1, JANUARY 2001:97-102
 ISSN 1118-0579

POROSITY AND COMPACTION TREND IN OKAN FIELD (WESTERN NIGER DELTA) BASED ON WELL LOG DATA

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(Received 6 January, 2000; Revision accepted 17 August, 2000)

ABSTRACT

Porosity and compaction trends in Okan Field have been highlighted based on the interpretation of well log data within the productive interval of 5000 to 10,000 ft. Six Porosity Zones have been delineated based on the interpretation of gamma - ray log from the representative wells. The zones that occurred between 5000ft and 8000 ft appeared to be tectonically controlled whereas the deeper zones result mainly from diagenetic changes associated with the burial history of the sediments. Regionally, these zones represent from bottom to top, cyclic deposition of clays and sands which become increasingly sandy upward through the sequence. Porosity values are in the range of 15 and 25% and this is good enough to enhance hydrocarbon accumulation in the area. Sedimentation pattern is normal in most parts of the field except for a local zone of overpressure observed at a depth of 8300ft in the northeastern section of the field. The main hydrocarbon trap results from vertical stacking of porous reservoirs sands while stratigraphic trap is evident from reservoir Pinch-outs.

KEY WORDS: Porosity, Reservoir, Sedimentation, Overpressure, Hydrocarbon.

INTRODUCTION

The analysis of porosity and compaction trends during hydrocarbon exploration is very important in any sedimentary basin. This is because through such analysis it would be possible to detect any zone of abnormal pressure which would be indicated by a reverse compaction trend. Once this is known, it would be possible to guide against blowout incident by an appropriate adjustment of the weight of the drilling fluids. Generally, a stratigraphic section that is normally compacted will show a decreasing trend in porosity values with increasing depth. Different methods for the evaluation of porosity and compaction abound in different exploratory units (Rider, 1986), but the choice of logging method is considered in this study to ascertain the workability of the method. Obviously, when reliable results are obtained from log analysis, this will serve as a best alternative to coring method which is rather more expensive and non continuous in terms of coring intervals among other short comings.

The causes of abnormal pressure are many, but based on the interpretation of logs alone, only the effect of compaction is considered. Abnormal Pressure zones are characterised by a geostatic pressure greater than 12.5 Kpa per meter which is very much higher than the normal hydrostatic pressure of 10.5 Kpa per meter. In a situation of this sort, the rate of deposition is believed to exceed the rate of sedimentation by an order of magnitude. According to Onuoha (1983), different formation characteristics (e.g, porosity and velocity) may be used in determining the depositional history of sediments and thus the detection of the presence or absence of an overpressure bed in any sedimentary basin. Also, Schlumberger

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(1972), clearly state that under normal compaction, porosity decreases with increase in depth. In the same vein, the interval transit time (Δt) made out from a sonic log through such a section should show a similar trend. Therefore in the presence of an abnormally pressured bed, the normal decrease in transit time will be reversed leading to larger transit time values at greater burial depth (Rider 1986). Hence by plotting transit times in shales or porosity against depth for any section of the stratigraphic sequence, it would be apparent to observe from the curve(s), compaction trend in the area and thus the detection of the presence or absence of an overpressure zone.

GEOLOGY OF THE AREA

The Okan field (Fig.1) from where the analysed logs were obtained is in the Western part of the Niger Delta and so the geology of the area is that of the typical Niger Delta Basin.

According to Weber and Daukoro (1976), Evamy et al. (1978), Reijers (19956), among others, three basic units - Benin Formation, Agbada Formation and the Akata Formation make up the lithostratigraphic units in the area. The Akata Formation is made up of undercompacted shales with some siltstones and sandstone. However, the stratigraphic section penetrated in the Okan field terminates at the lower part of the Agbada Formation which is made up of undercompacted shales with some siltstones and sandstones. The unit is purely marine in origin. The Agbada Formation is a Parallic succession comprising of alternation of sand and shale units. The sands are medium grain (0.25 to 0.5mm) and greyish. The Benin Formation, a continental deposit is composed mainly of coarse grained sands with some gravels.

MATERIALS AND METHOD

The materials used in the analysis came from Okan field which is located 2 to 3.5 km from the shoreline just west of the estuary of Escravos River (Figure 1). All the logs were

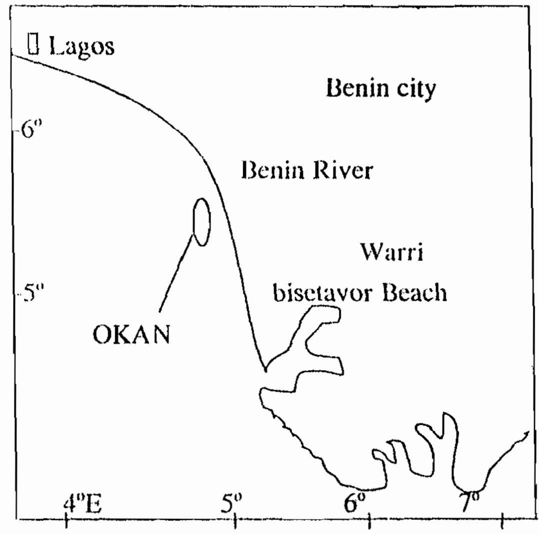

Fig 1 Okan field location Map (Modified from chevron concessions maps 1890).

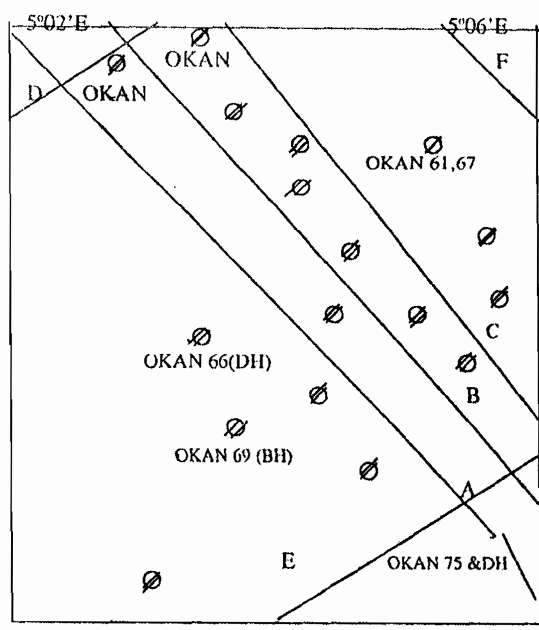

Fig. 2 Map of the study area showing studied wells and seismic lines.

processed and supplied by Chevron exploration unit, Lagos. The well log data were made from six different wells which include Okan 75, Okan 61, Okan 74 and Okan Bd_4. These wells are randomly spread within the field (Figure 2). Such that a larger area of the field was covered. The logs provided include compensated neutron log (CNL), compensated

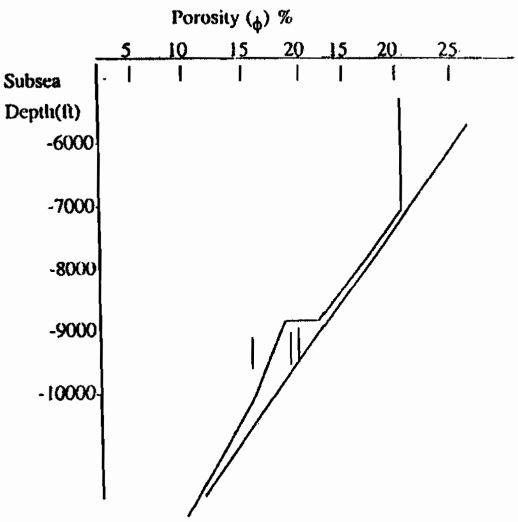

Fig. 3. Compaction trend in Okan 69 well. (i) field data curve (ii) Presumed trend for normal compaction condition.

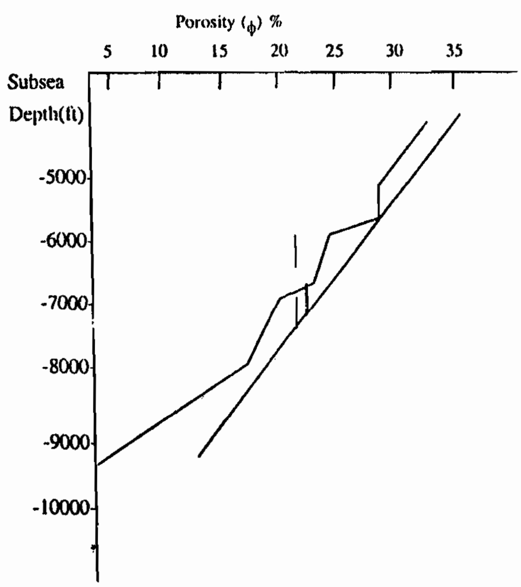

Fig.4 compaction trend in Okan Bd 4 well.
(i) Field data curve (ii) Presumed trend for normal compaction condition.

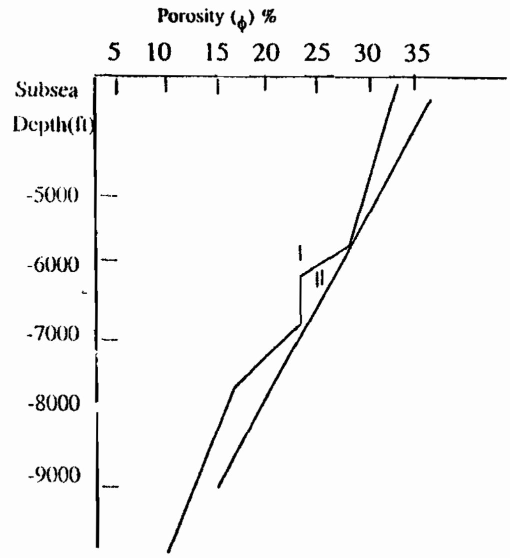

Fig. 5 Compaction trend in Okan 66 well.
(i) Field data curve (ii) Presumed trend for normal compaction condition.

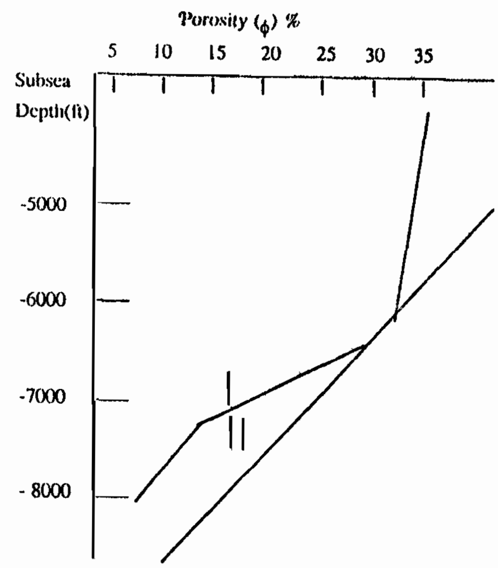

Fig. 6. Compaction trend in Okan 61 well.
(i) Field data curve (ii) Presumed trend for normal compaction condition.

density log (CDL), the resistively logs and gamma-ray log. These logs were interpreted for such formation parameters as porosity, density, water saturation, as well as the lithologic units based on the log-head scale on each of them. In doing so, each value read from them was further adjusted by crossplotting the neutron reading with the density reading using appropriate lithologic unit to the actual value. In the same vein, the readings of the CNL which is based one the measured ratio between the far and near detectors of the device is generally much less sensitive to environmental changes than a single detector would be (Rider, 1986). Therefore the log-derived data were environmentally corrected. Porosity and density values obtained from these logs were then plotted against depth for each of the wells from the curves obtained, the compaction trend in the field was examined. In the same vein, the interval transit times for shales Δt_{sh} was determined and a plot of it

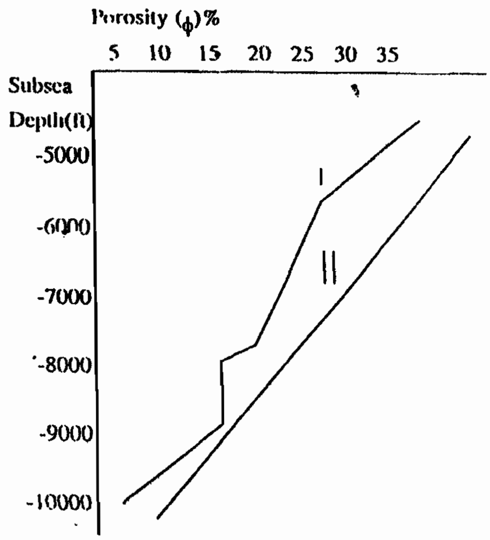

Fig 7. Compaction trend in Okan 75 Rd well.
(i) Field data curve (ii) Presumed trend for normal compaction condition.

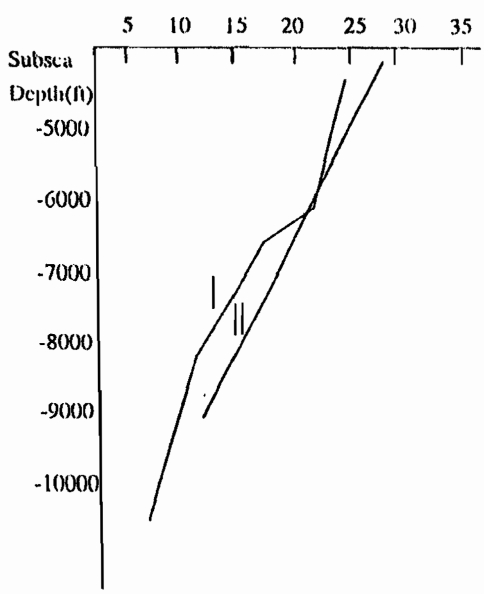

Fig. 8 Compaction trend in Okan 74 well.
Field data curve (ii) Presumed trend for normal compaction condition.

against depth made for compaction evaluation. Reservoir zones were delineated from the gamma-ray log and correlated from well to well based on similar pattern displayed on the electric logs.

RESULTS AND DISCUSSION

Tables 1 - 7 and Figures 3-9 show the reservoir parameters and the compaction trends respectively in each of the wells in the study area. The reservoir units encountered in the study area are of variable thicknesses ranging from a minimum of 8ft in well Okan 69 to a maximum of 67ft encountered in the H - sands in well Okan 75Rd. Porosity values ranged between 13 - 28.1% in the area.

According to Archer. (1986), a petroleum reservoir should have porosity not less than 15% for it to be of economic value in terms of hydrocarbon yields. This implies that t reservoirs of Okan field have the potentials producing hydrocarbon in commercial quanti giving that other hydrocarbon generati requirements of the source rock in the area a met.

A critical look at figures 3 - 9 sho that sedimentation in the field is normal bas on the normal compaction curves displayed the area. Porosity does not appear to ha been affected by over presuring cementation, as indicated by the line decrease in porosity trend with increasi depth inspite of a palpable local over pressu observed in well Okan BD - 4 in tl northeastern part of the field. This stro correlation of increasing burial depth wi increasing compaction according to McBride i

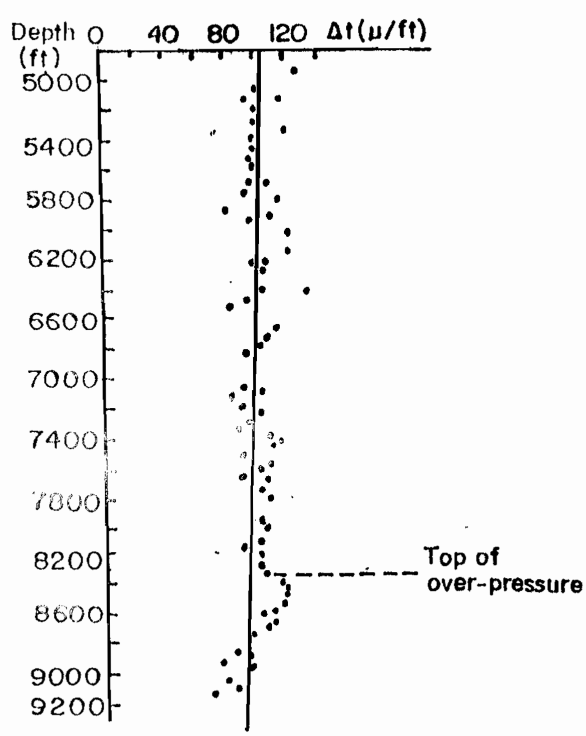

Fig. 9 Plot of transit time versus depth showing an over-pressure zone.

al. (1980) indicates that compaction of sandstone reservoirs is almost entirely the result of overburden pressure. The presence of this local overpressure bed is evident from the change in the normal decreasing trend in porosity with increasing depth of burial. The interval transit time (Δt) values of Table 7 is similarly observed to increase where the overpressure occurred (Figure 9). Therefore the shales in the region are undercompacted and consequently the estimated porosity values are higher even after the correction of borehole effects using appropriate correction charts was done. The high porosity values obtained in this case apparently implies low velocity in view of the inverse relation that exist between them (Asquith and Gibson, 1983). The top of the overpressure is at 8,300ft (2500m) and has a thickness of about 110ft (30m). According to Archer (1986), any hydrocarbon bearing structure of substantial relief will exhibit abnormally high pressures at the crest when the pressure at the hydrocarbon - water contact is normal, simply because of the lower density of hydrocarbon compared with water.

The absence of a geopressured bed in the Southern part of the field is an indication of the fact that the major fault which transcended the area may have sealed the reservoir in all directions. Helander (1983) believed that such sealing effect or the lensing - out of the affected sand bodies in the area could hinder the dissipation of the high pressure generated in an adjacent unit. Therefore, drilling in that section of the field may be done without any risk of blow-outs. The fact that the sediments of the Okan field are highly compacted is clearly seen from the low porosity of the various reservoir units both at intermediate and deeper burial depths. However, the degree of compaction is observed to vary from one reservoir unit to another as burial depth changes. This variation in the degree of compaction directly reflects the amount of the net porosity available in the different reservoir units.

Table 1: Reservoir Units of Okan 96 Well

Reservoir Zone	Subsea depth (ft)	Unit designation	Thickness (ft)	Mean porosity (%)
1	- 6523	J – sands	44	29
2	- 7073	K – sands	8	28.1
3	- 7249	L – sands	14	27
4	- 7603	M – sands	190	26
5	- 7913	N – sands	110	24
6	- 8019	O – sands	640	22.9
7	- 8781	P - sands	256	20.3
8	- 9127	Q - sands	420	18.1

Table 2: Reservoir Units of Okan 75 Rd Well

Reservoir Zone	Subsea depth (ft)	Unit designation	Thickness (ft)	Mean porosity (%)
1	- 6829	E – sands	300	32
2	- 7209	G – sands	278	29
3	- 7529	H – sands	678	26
4	- 8303	J – sands	250	24
5	- 8687	K – sands	10	23
6	- 8889	L – sands	30	22
7	- 8997	M – sands	230	20
8	- 9553	N - sands	20	19
9	- 9659	Q – sands	252	17

Table 3: Reservoir Units of Okan 61 Well

Reservoir Zone	Subsea depth (ft)	Unit designation	Thickness (ft)	Mean porosity (%)
1	- 5118	E – sands	580	34
2	- 5898	G – sands	260	32
3	- 6188	H – sands	50	29
4	- 6548	K – sands	400	23
5	- 7066	L – sands	500	10
6	- 7508	M - sands	100	18

Table 4: Reservoir Units of Okan 66 Well

Reservoir Zone	Subsea depth (ft)	Unit designation	Thickness (ft)	Mean porosity (%)
1	- 5590	E – sands	460	27
2	- 6120	G - sands	240	25
3	- 6550	H – sands	140	22
4	- 7040	K – sands	80	19
5	- 7510	L sands	50	18.3
6	- 7750	M - sands	100	16.4
7	- 8060	N sands	190	14.3
8	- 8480	O - sands	550	13

Table 5: Reservoir Units of Okan 74 Well

Reservoir Zone	Subsea depth (ft)	Unit designation	Thickness (ft)	Mean porosity (%)
1	- 5334	E – sands	500	23
2	- 6064	G - sands	250	21
3	- 6334	H - sands	300	20.1
4	- 6824	J - sands	60	18
5	- 6994	K – sands	30	17
6	- 7174	L - sands	10	15.2
7	- 7494	M – sands	250	14
8	- 7814	N - sands	50	12
9	- 8184	O – sands	950	11.2
10	- 9444	P - sands	250	9

Table 6 Reservoir Units of Okan 96 Bd$_4$ WELL

Reservoir Zone	Subsea depth (ft)	Unit designation	Thickness (ft)	Mean porosity (%)
1	- 5536	E – sands	200	24
2	- 5866	G – sands	40	23
3	- 5936	H – sands	350	21
4	- 6446	J – sands	50	18
5	- 6626	K - sands	160	14
6	- 7197	L – sands	60	13.3
7	- 7481	M - sands	350	9.23
8	- 7997	N – sands	150	10.9
9	- 8260	O - sands	1,290	14.5
10	- 8400	P – sands	140	12

CONCLUSION Porosity derived from log is an invaluable parameter for the determination of compaction trend in an oil field when compared with core derived porosity. Apart from a local zone of overpressure observed in one section of the field, the sedimentation and depositional patterns are normal in the field. Most of the reservoirs have mean porosities between 17 and 25% and this is very favourable for hydrocarbon accumulation when compared with the standard 15% porosity necessary for any commercial accumulation of hydrocarbon to occur in a sedimentary basin. Most of the reservoir units similarly have thicknesses greater than 250ft. This is also significant since commercial accumulation of hydrocarbon have been documented in reservoirs sections having thicknesses in the range of 150 to 200ft. There is a great optimism that drilling could be done in the Okan field without the least incidence of blow-out. The use of the environmentally dependent logs required that appropriate borehole corrections be made to the data generated from them.

Table 7 Interval transit time in well BD_4

Depth (ft)	Transit Time (s/ft)	Depth (ft)	Transit Time(s/ft)
5000	126	6200	105
5050	88	6250	97
5100	92	6300	103
5150	96	6350	100
5200	113	6400	103
5250	97	6432	135
5300	113	6450	93
5350	88	6500	80
5400	98	6550	N V
5450	100	6600	N.V.
5500	99	6650	114
5550	101	6700	102
5600	104	6750	100
5650	96	6800	90
5700	10	6850	104
5750	80	6900	120
5800	117	6950	110
5850	115	7000	125
5900	108	7050	90
5950	97	7100	100
6000	100	7150	93
6050	100	7200	100
6100	121	7250	97
6150	100	7350	85

*N.V Not Visible

ACKNOWLEDGEMENT

We are most grateful to Chevron Nigeria Limited, Lagos for supplying the log suites used in this work. We are thankful to the department of Petroleum Resources, Lagos for their consent.

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